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SOME COMPARISONS OF THE FLYOVER NOISE CHARACTERISTICS OF DC-9 AIRCRAFT HAVING REFANNED AND HARDWALLED JT8D ENGINES, WITH SPECIAL REFERENCE TO MEASUREMENT AND ANALYSIS PROCEDURES

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16. Abstract

Flyover noise measurements were made (using Federal Aviation Regulations, part 36 procedures) of two DC-9 aircraft, one equipped with refanned JT8D-109 engines and the other equipped with hardwalled JT8D-9 engines. The measurements were made in parallel by NASA and Douglas Aircraft Company (DACO) personnel at the DACO Yuma, Arizona, test site. NASA analyses show a refan centerline noise reduction of about 9.1 EPNdB and 10.0 EPNdB for takeoff with cutback and 50° flap landing approach, respectively. A comparison of refan and hardwall PNLTM spectra shows that the refan noise reduction may be attributed to lower jet noise levels on takeoff and reduced high-frequency tonal content on landing approach. The main body of this report provides a general description of the test procedures and results. The appendices contain detailed descriptions of the measurement and analysis systems and procedures.

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INTRODUCTION

The objective of the NASA Refan Program under the direction of the Lewis Research Center (ref. 1) was to demonstrate the use of current noise abatement technology to quiet the narrowbody fleet of jet transports. The plan for technology utilization called for reducing both the jet and fan noise. Jet noise reductions were obtained by decreasing jet core velocities through increased turbine work and by decreasing the fan duct jet velocity by employing a lower fan pressure ratio and a higher bypass ratio. Fan noise was reduced by substituting a single-stage fan for the two-stage fan in the baseline engine and by using acoustic treatment in the engine and nacelle. References 2 and 3 provide further details on the refan program and engine modifications.

Between January 21, and March 4, 1975, the acoustic benefits of the Refan Program were documented by NASA-Langley and Douglas Aircraft Company (DACO) personnel in flight tests at the DACO test site in Yuma, Arizona. The two test aircraft were (a) A McDonnell-Douglas owned DC-9-31 (fig. 1) equipped with Pratt and Whitney JT8D-109 (refanned) engines with acoustically treated nacelles, and (b) a USAF C9A (DC-9-32) (fig. 2), equipped with JT8D-9 engines with hardwall nacelles. The

aircraft were flown and parallel sets of noise measurements were made in accordance with the procedures of reference 4. Following the noise measurement phase of the test program the data were analyzed in parallel as specified in reference 4.

The purpose of this report is to provide a general description of the test and analysis procedures used by the NASA and DACO measurement teams and to compare results. The 1/3 octave band flyover time history data, on which the NASA results are based, are not included. However, these data can be made available to interested researchers on request.

SYMBOLS

A	Aircraft altitude, m (ft)
b_a	Distance of closest aircraft approach to projection of microphone position on actual ground track, m (ft)
b_r	Distance of closest aircraft approach to projection of microphone position on referenced ground track, m (ft)
c	Speed of sound, m/sec (ft/sec)
d	Duration of significant PNLT time history, sec
dB(A)	A-weighted sound pressure level, dB
EPNL	Effective perceived noise level, EPNdB
F_n/δ	Engine normalized static thrust (power setting), N (lbf)
L	Lateral deviation of microphone from ground track, m (ft)
PNL	Perceived noise level, PNdB
PNLM	Maximum perceived noise level, PNdB
PNLT	Tone-corrected perceived noise level, PNdB
PNLTM	Maximum tone-corrected perceived noise level, PNdB
SC	Speed correction, EPNdB

SPL	Sound pressure level, re 2×10^{-5} N/m^2, dB
SR	Slant range, m (ft)
t_o	Time aircraft is overhead projection of microphone position on ground track, sec
t_m	Time for which PNLTM is received, sec
V	Aircraft flight track speed, m/sec (ft/sec)
α_i	Atmospheric sound absorption coefficient for the i^{th} 1/3 octave band, dB/km (dB/1,000 ft)
α_a	Angle between the actual flight track, the aircraft position on that flight track when PNLTM spectrum is emitted, and the actual microphone position, deg
α_r	Angle between the reference flight track, the aircraft position on that track when PNLTM spectrum is emitted, and the reference microphone position, deg
γ	Flight track angle, deg
Δ	Difference in sound pressure levels, dB or EPNdB
Δ_a	Actual distance of closest approach, m (ft)
Δ_r	Reference distance of closest approach, m (ft)
Δ_2	Duration correction, EPNdB

Abbreviations

DACO	Douglas Aircraft Company
FAR-36	Federal Aviation Regulation, part 36
FM	Frequency modulated
IRIG	Interrange Instrumentation Group
Mic	Microphone
NBS	National Bureau of Standards

Subscripts

a	Actual (measured)
AVE	Average
i	The i th 1/3 octave band
r	Reference

DESCRIPTION OF TEST AND NOISE MEASUREMENT PROCEDURES

The noise measurement portion of the test program was divided into the following three joint NASA-DACO phases:

1. A noise measurement systems comparison test
2. The refan flyover noise measurements (designated "refan I")
3. A combination of hardwall and refan flyover noise measurements (designated "hardwall" and "refan II," respectively)

The noise measurement systems comparison test was used to determine how nearly alike the two organizations would measure and analyze the acoustic characteristics of the same noise source and to determine the reasons for any differences. The noise sources for these measurements were the landing approaches of commercial DC-9 traffic into Yuma International Airport.

The refan I test was designed to produce certification-type noise data for the refanned aircraft and the hardwall-refan II tests were designed to produce similar data for the hardwalled and refanned DC-9 aircraft under as nearly alike weather conditions as possible. These last two phases included full power takeoff corrections, takeoffs with cutback, cutback corrections, landing approach corrections, and 50° flap landing approaches.

The NASA and DACO parallel noise measurements were made along the extended centerline of runway 3-21 at location C5 (see fig. 3) for the systems comparison test and at locations C6 and C10 for the refan and hardwall takeoffs and landing approaches, respectively. (DACO also made centerline and sideline noise measurements at the other positions shown in fig. 3.) A microphone array similar to that shown in figure 4 was used at all the parallel measurement locations. The NASA microphones were located 45.7 cm on either side of the DACO microphones, with the microphone stands alined along the ground track. The microphone diaphragms were oriented for grazing incidence at a height of 1.2 m.

The microphone systems used by the NASA are described in appendix A. All system microphone channels were field calibrated prior to, and at the end of, each test day using the procedure outlined in the field system calibrations section of appendix A.

All aircraft tracking, performance, and 10 m temperature and relative humidity data were recorded by the DACO. With the exception of the hardwall flights for takeoff corrections, cutback corrections, and landing approach corrections, none of the noise data were recorded under temperature inversion atmospheric conditions. IRIG B time code, synchronized with DACO time code to within ± 0.25 seconds, was recorded on the NASA data tapes.

For the noise measurement systems comparison test NASA and DACO exchanged pistonphone calibrators and recorded their output on tape. Pink noise and pure tone calibrations (at the center frequency of each

octave band from 50 Hz to 10 KHz) were also recorded simultaneously by NASA and DACO. These three calibrations were included in the pre- and postcalibrations for this phase of the test program only. For the remaining test phases, only the pistonphone exchange and simultaneous pink noise calibration were routinely included in test day pre- and postcalibrations.

DATA ANALYSIS AND RESULTS

This section presents a detailed description of the data analysis procedures used for each of the test program phases mentioned in the preceding section.

Noise Measurement Systems Comparison Test

Following the previously described parallel systems precalibrations, the noise from four landing approaches of commercial jet transports were simultaneously recorded by NASA and DACO at location C5 (fig. 3). No tracking or weather data were recorded for these flyovers. To compare the DACO and NASA noise measurement and analysis techniques, three separate sets of tests were performed:

a. Analyses of both DACO and NASA data tapes by DACO using DACO calibrations (results shown in table 1).

b. Analyses of NASA data tapes by NASA and DACO using DCAO calibrations (results shown in table 2).

c. Analyses of the NASA data tapes by NASA using both NASA and DACO calibrations (results shown in table 3).

The results of these analyses and a comparison of 1/3 octave band spectra at the time of PNLM are presented in tables 1-4. The analyses included pink noise, slow response, wind screen, and microphone electrostatic response corrections. No flightpath, performance, or weather corrections are included in the data of tables 1-4 and the results shown should not be interpreted as landing approach certification numbers.

Table 1 presents a comparison of the NASA and DACO-measured noise levels as analyzed by DACO at their Long Beach Laboratory (a. above) for one of the commercial aircraft landing approach noise test runs. The Δ column contains values of the numerical differences between averages of the two DACO measurements and the two NASA measurements, respectively. The Δ's listed are representative of the small differences in system outputs observed for all runs, with the exception that the signs varied in such a manner that there was no obvious system sensitivity bias.

Table 2 presents a comparison of NASA and DACO analyses of NASA data tapes (b. above) in order to provide a direct comparison of analysis procedures. Table 3 presents a comparison of the results obtained from use of both the NASA and DACO calibrations (c. above) which utilized similar equipment and operational procedures. The differences observed in the Δ columns of tables 2 and 3 are similar in nature to those in table 1.

Table 4 presents a comparison of NASA-measured PNLM 1/3 octave band spectra as separately analyzed by NASA and DACO along with observed 1/3 octave band level differences. The individual 1/3 octave

band levels show agreement within 1 dB for all but the 50 Hz, 63 Hz, 125 Hz, and 200 Hz bands. Although closer agreement of the levels in these low frequency bands would be desirable (the largest difference was 4.3 dB in the 200 Hz band), their effect on the calcualted EPNL values was negligible.

Based on these results, the calibration, measurement, and analysis procedures used by NASA and DACO seem to be comparable. Therefore, possible differences in the noise measurements and analyses of the refan and hardwall engine data were expected to be of the order of magnitude of those in tables 1-3.

Refan I Flyover Noise Measurements

Between January 28, 1975, and February 2, 1976, the noise from more than 60 refan flyovers were recorded by NASA and DACO. To help fulfill the objectives of these measurements, the 20 data points identified in table 5a from one microphone channel were analyzed as specified in reference 4. Using DACO-furnished performance, tracking, and weather data (see ref. 5 for a description of the DACO test range) the associated noise measurements were corrected to the reference conditions specified in reference 4. There are several areas in reference 4 where the interpretation may vary from organization to organization. Appendix D describes these areas and the interpretation chosen for the NASA analyses.

The analysis procedure may be thought of as a three part process. First, all of the data were corrected to the reference flightpath and weather conditions. Then, takeoff correction and landing approach correction EPNL's were plotted against F_n/δ and fit with a linear

curve determined by using the method of least squares. Finally, these curves were used to provide thrust correction values to be added directly to the flightpath and atmospheric absorption – corrected EPNL's for takeoff with cutback and 50° flap landing approach. Figures 5 and 6 show the refan I takeoff and landing approach correction curves, respectively.

Tables 6 and 6b present a summary of the analysis results from all the refan I flyovers analyzed by NASA in metric and english units, respectively. Shown in the tables are values of the reference and actual conditions as well as the uncorrected and corrected noise levels for the refan I flights. The average centerline refan I takeoff with cutback and landing approach EPNL's obtained from these analyses were 89.8 EPNdB and 98.9 EPNdB, respectively.

Hardwall-Refan II Flyover Noise Measurements

Between February 25, 1975, and March 4, 1975, 41 hardwall and 22 refan II flyover noise measurements were recorded. The hardwall flyovers consisted of a complete series of takeoff and landing approach corrections, cutback corrections, takeoffs with cutback, and 50° flap landing approaches. The refan II flyovers consisted of takeoffs with cutback and 50° flap landing approaches flown back-to-back with the comparable hardwall flyovers. These refan II data provided a direct comparison of noise levels with the hardwalled aircraft under as nearly identical atmospheric conditions as possible.

From these flyovers, the 24 data points shown in table 5b were analyzed in a manner identical to that used on the earlier refan I analysis;

the only exception was that the takeoff and landing approach correction data from the refan I analysis were applied to the refan II data. Figures 7 and 8 show the hardwall takeoff and landing approach correction curves, respectively. Although the slopes of these curves are nearly equal to those for the refanned aircraft (compare figs. 5 and 7 and figs. 6 and 8), the refan slopes are slightly greater on takeoff and slightly less on landing approach than the hardwalled slopes.

Table 7 presents a summary of the hardwall analysis results while table 8 presents a summary of the refan II analysis. The format for tables 7 and 8 is the same as that previously used for table 6. The average hardwall centerline EPNL's for takeoff with cutback and 50° flap landing approach are 96.6 EPNdB and 108.9 EPNdB, respectively. For the refan II analyses, the levels were 86.0 EPNdB and 99.0 EPNdB for takeoff with cutback and 50° flap landing approach, respectively.

These numbers as derived from the hardwall-refan II tests would seem to imply that the refanned aircraft noise levels are 10.6 EPNdB lower on takeoff with cutback and 9.9 EPNdB lower on landing approach. It will be remembered, however, that the refan I takeoff-with-cutback level was 89.8 EPNdB, a value 3.8 EPNdB higher than for refan II Data of tables 6 and 8 seem to indicate that the descrepancy is caused by a large difference in the refan I and refan II duration factors. The reason for the difference in the duration factors can be explained by using the data of figures 9 and 10. Figure 9 is a PNLT time history from one of the refan I takeoff-with-cutback flights and figure 10 is

a PNLT time history from a similar refan II flight. The x's on each figure show the time interval over which the duration factor is computed. It is seen in figure 9 that the time interval has shrunk to one point whose level was less than 90 PNdB. Therefore, the duration factor was computed to be 0 EPNdB. In figure 10, however, the significant time interval lasts 4 seconds, resulting in a -4.7 EPNdB computed duration factor. The above 3.9 PNdB difference in the two sets of measurements is, thus, believed to be due to a computation procedure anomaly rather than differences in measurement equipment and procedures. Appendix D provides a more detailed explanation of this anomaly.

A more representative noise level for the refan takeoff-with-cutback condition might be the average of the five refan I and refan II flights. This gives a level of 87.5 EPNdB for the refan takeoff with cutback. A similar procedure for landing approach gives a level of 98.9 EPNdB. Subtracting these levels from the hardwall values indicates that the refanned airplane provides an apparent 9.1 EPNdB noise reduction on takeoff with cutback and a 10.0 EPNdB noise reduction on landing approach. These noise reduction data are summarized in table 9.

DISCUSSION OF RESULTS

The average centerline EPNL's for the refan I, hardwall, and refan II analyses which have been compiled in table 9, show that the refan I and refan II data, although measured several weeks apart and under different 10 m temperature and relative humidity conditions (see tables 5-8) agree within 0.1 EPNdB for landing approach and 3.8 EPNdB for takeoff with cutback. The 3.8 EPNdB difference on takeoff has been

attributed to duration factor effects in computation rather than atmospheric effects. It is also seen that the centerline noise reduction is about 9.1 EPNdB for takeoff with cutback and 10.0 EPNdB for landing approach. It should be noted that the data in table 9 are averages of from three to five data points. It is possible that a more extensive set of data might give different results.

The reason for the lower refan noise levels is illustrated in figures 11 and 12. Figure 11 presents a comparison of the hardwall and refan weather-plus-path corrected (see appendix D), PNLTM, 1/3 octave band spectra for centerline takeoff with cutback (runs 12 and 31, respectively). Figure 12 presents the same type of data for 50° flap landing approach (hardwall run 5 and refan run 27). The reduced noise levels at the lower frequencies are believed due to jet exhaust noise reductions whereas the lower levels at the higher frequencies are believed to be associated with fan noise reductions. Because of a low signal to ambient noise ratio at frequencies above 2.5 KHz for the refan spectrum and above 3.15 KHz for the hardwall spectrum, the levels have been estimated as indicated by the shaded portions of each curve. The slope of this portion of the curve is assumed to be – 6 dB per octave, a value consistent with the jet noise spectrum values published in reference 6.

CONCLUDING REMARKS

FAR-36 type noise measurements and analyses of selected refan and hardwall DC-9 aircraft flyovers were made in parallel with the

Douglas Aircraft Company at the DACO Yuma, Arizona, test site in order to evalute the refan modifications as well as data acquisition and analysis procedures.

NASA analyses of the refan and hardwall data indicated that the refanned aircraft provided a centerline noise reduction of about 9.1 EPNdB for takeoff with cutback and about 10.0 EPNdB for 50° flap landing approach.

A limited comparison of results from NASA and DACO measurements and analyses for landing approach conditions indicated agreement within ±1 EPNdB.

The worst repeatability results (±3.8 EPNdB) were obtained for the refan takeoff-with-cutback condition. It is believed that the difficulty is associated with the duration factor computation rather than being due to measurement systems performance or atmospheric effects.

APPENDIX A

AIRCRAFT FLYOVER NOISE MEASUREMENT SYSTEM DESCRIPTION AND CALIBRATION PROCEDURES*

INTRODUCTION

This appendix presents a technical description of the data acquisition system used by NASA Langley Research Center in the Refan Aircraft Flyover Noise Measurement Program.

The system consisted of the microphones, cables, signal conditioning, and recording equipment necessary to obtain flyover noise data in accordance with Federal Aviation Regulations, part 36. It incorporated field proven, commercial hardware from recognized manufacturers. Included in this documentation is a narrative description of the system, tabulation of pertinent specifications, and block diagrams. Calibrations and test procedures employed to verify system performance are also discussed.

SYSTEM DESCRIPTION

A data acquisition system block diagram for a typical microphone channel is shown in figure A1. Principal system components are pressure microphones with accessary windscreens and preamplifiers, variable-gain amplifiers, and an FM tape recorder. An oscillograph was used for

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*Certain commercial equipment and materials are identified in this paper in order to adequately specify the experimental procedures. In no case does such identification imply recommendation or endorsement of the products by NASA, nor does it imply that the equipment or materials are necessarily the best available for the purpose.

infield data verification and to establish optimum recording levels. No preemphasis filter networks were used. Specifications for all commercial hardware items are tabulated from the manufacturers' manuals in appendix B. The microphones were configured with the standard grid cap, a Bruel and Kjaer Model UA0237 windscreen, and were oriented for grazing incidence at a height of 1.2 m. To accommodate 450 m signal cables, Bruel and Kjaer Model 2804 power supplies with a factory installed integral line driver was used. The tape recorder was operated at 76.2 cm/sec (IRIG Intermediate Band FM) within an IRIG B 1,000 Hz modulated time code signal recorded simultaneously with the microphone data in all cases.

LABORATORY SYSTEM CALIBRATION

Prior to the field noise measurement program, extensive calibration and testing were conducted to verify proper system operation and to document system performance. Specifications for acoustic calibration devices used are included in appendix C.

All system components for each data channel were individually calibrated in accordance with the manufacturers' recommended procedures, or alternate methods approved by the NASA. General calibration laboratory policies and procedures were as recommended in reference 7. All test measurements were made with instruments whose calibrations are traceable to the NBS. To determine microphone frequency response, an electrostatic calibration was performed using a Bruel and Kjaer Model 4142

microphone calibration apparatus. Microphone sensitivity was determined using a Bruel and Kjaer Model 4220 pistonphone.

Components were assembled and the critical parameters of frequency response, distortion, linearity, and noise floor were documented. System level tests are summarized in table A1. Typical system frequency response plots are shown in figure A2. The roll-off at high frequencies exhibited by all frequency response plots is a function of the low-pass filter in the tape recorder reproduce electronics; this was the only deviation from straight-line response above 20 Hz.

FIELD SYSTEM CALIBRATION

All system microphone channels were field calibrated prior to each test day as follows:

1. End-to-end system sensitivity was determined using a B&K Model 4220 pistonphone. The calibration signal of 124 dB at 250 Hz was recorded on magnetic tape and the barometric pressure was noted in the tape log.
2. An oscillator signal was inserted at the preamplifier input and system frequency response was certified through the tape recorder.
3. A pink noise signal from a General Radio Model 1382 random noise generator was inserted at the preamplifier input and recorded on magnetic tape as a frequency response reference for subsequent data reduction.
4. The pistonphone was checked daily versus a reference microphone.

At the conclusion of the test day, calibrations 1, 3, and 4 were repeated.

TABLE A1

SUMMARY OF SYSTEM LEVEL TESTS

TEST	PROCEDURE	TEST RESULTS DC-9 REFAN PROGRAM
Frequency Response* (45 Hz to 11.2 KHz)	Apply oscillator signal at preamplifier input. Record system frequency response through tape recorder output.	± 0.5 dB
Distortion	Apply signal at microphone using acoustic calibrator. Check system distrotion through tape recorder output.	< 1 percent
Linearity	Apply oscillator signal at preamplifier input. Check system linearity at tape recorder output over expected range settings of variable-gain amplifier.	± 1.0 percent of full-scale tape recorder deviation
Noise Floor (ref. 2×10^{-5} N/m^2)	Short circuit preamplifier input and monitor system noise level at tape recorder output.	35-46 dB

*with respect to the calibration signal at 250 Hz

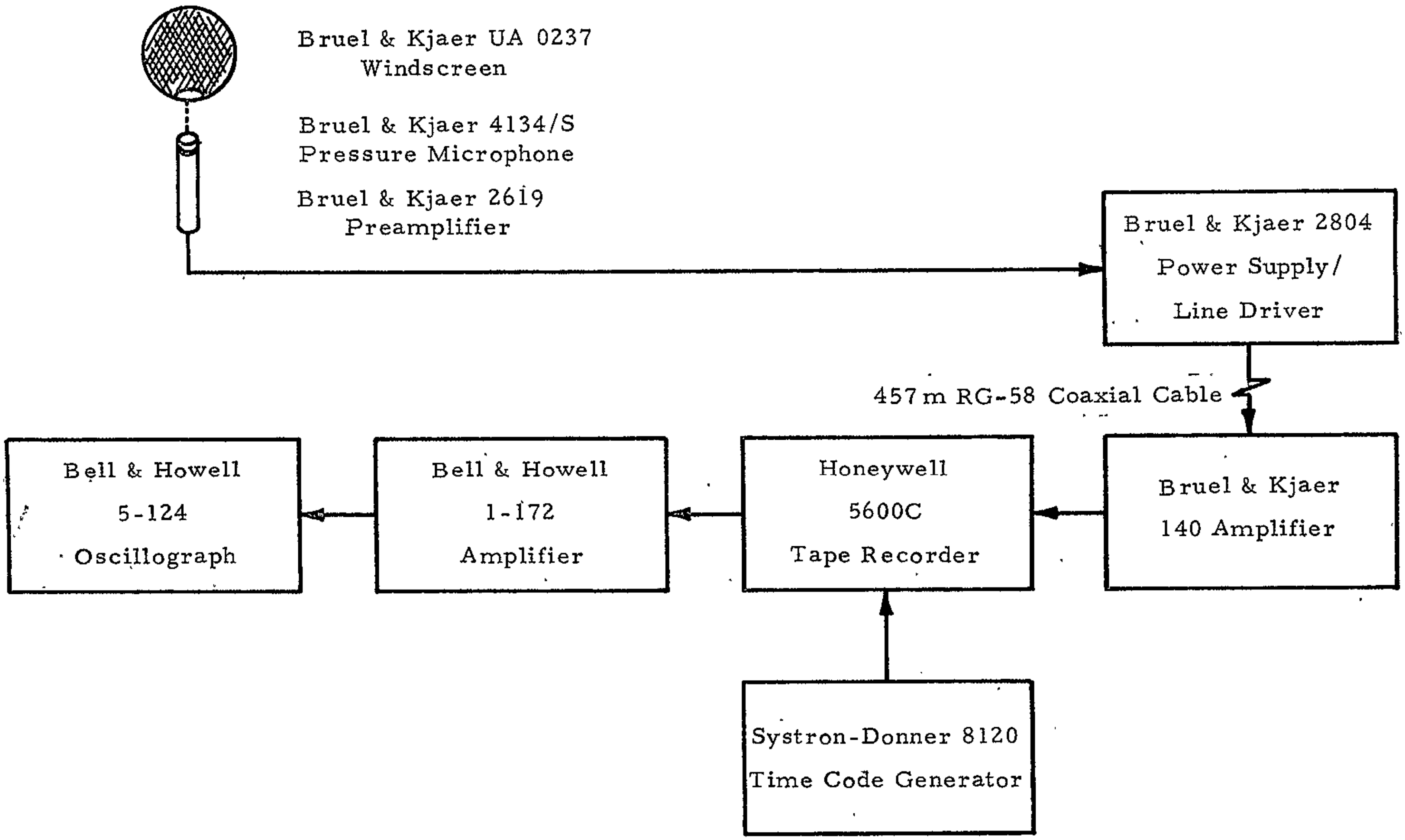


Figure A1. - Instrumentation block diagram - DC-9 refan noise measurement at Yuma.

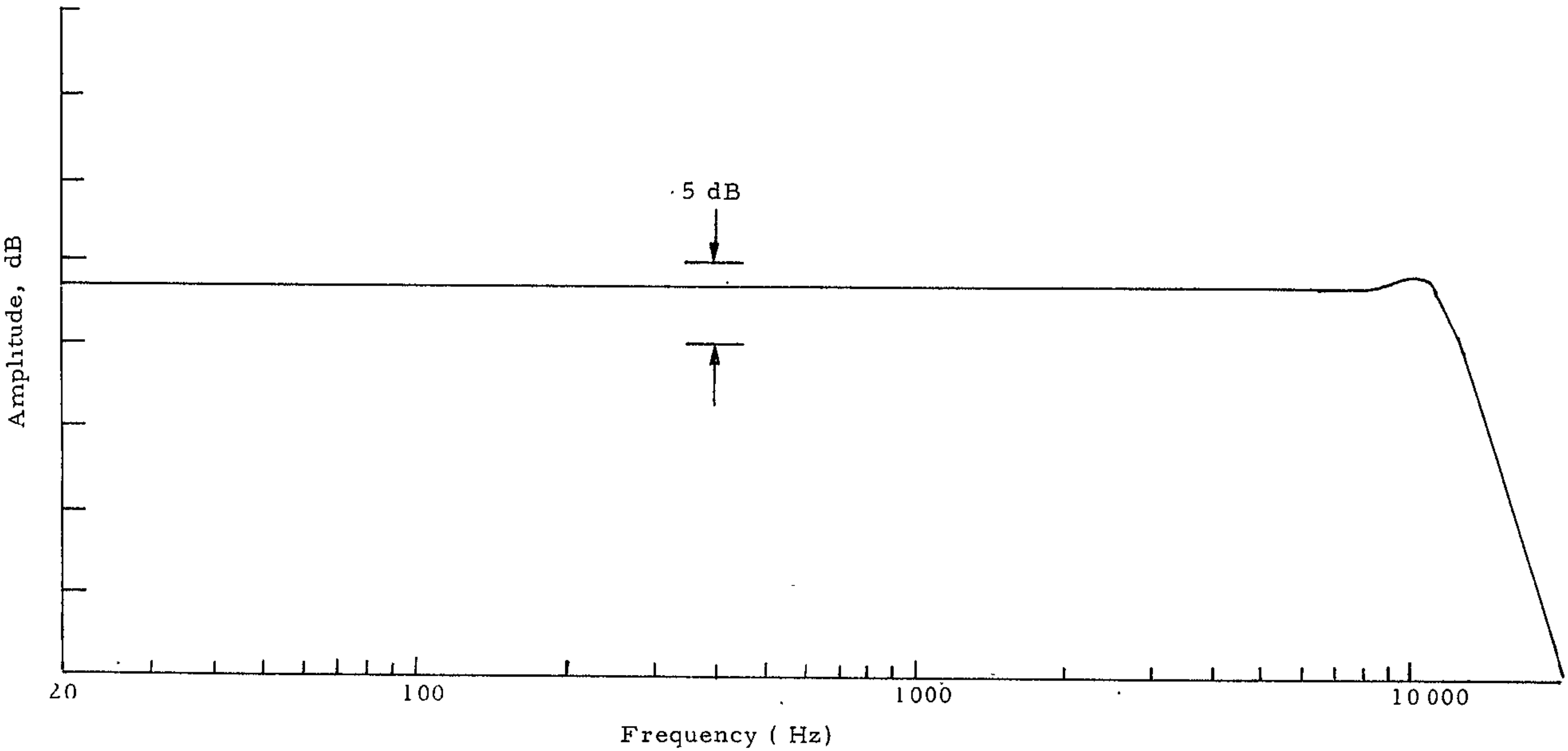


Figure A 2. - Typical microphone channel frequency response for DC-9 refan noise measurements.

APPENDIX B

MANUFACTURERS' SPECIFICATION FOR MICROPHONE SYSTEM COMPONENTS

This appendix contains the manufacturers' specifications for the microphone system components used in this test program as shown in figure A1. The specifications are presented in the following order:

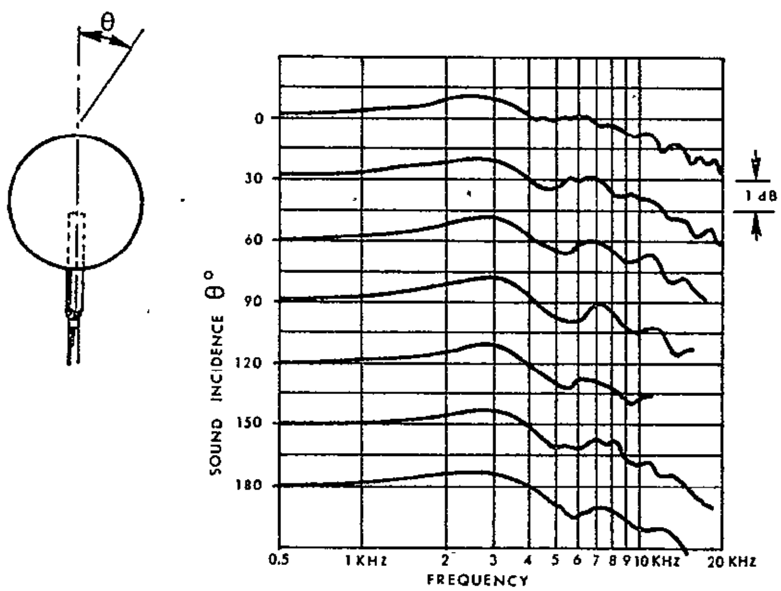
1. Bruel and Kjaer Model 4134/s microphone and UA0237 windscreen
2. Bruel and Kjaer Model 2619 preamplifier
3. Bruel and Kjaer Model 2804 power supply
4. Bruel and Kjaer Model 140 amplifier
5. Honeywell Model 5600 magnetic tape recorder
6. Systron-Donner Model 8120 time code generator
7. Bell and Howell Model 1-172 galvanometer amplifier
8. Bell and Howell Model 5-124 oscillograph

MICROPHONE, BRUEL AND KJAER, MODEL 4134

Specifications

Diameter:	1/2 inch
Polarization Voltage:	200 volts
Open Circuit Sensitivity:	12.5 mV per N/m^2 at 250 Hz
Frequency Response (pressure):	10 Hz to 5 kHz $\pm$ 0.5 dB 5 Hz to 10 kHz $\pm$ 1.5 dB 4 Hz to 20 kHz $\pm$ 2.0 dB

Free-field frequency response corrections for a microphone with the UA0237 windscreen are shown in the following curves.



Dynamic Range: (open circuit)	Lower limit determined by preamplifier noise. Upper limit 164 dB (ref. $2 \times 10^{-5}\ N/m^2$)
Capacitance:	18 pF (polarized)

MICROPHONE, BRUEL AND KJAER, MODEL 4134 (continued)

Temperature Range:	-50 to +60° C, temperature coefficient better than 0.006 dB/° C
Influence of Ambient Pressure:	-0.1 dB/100 mm Hg
Influence of Humidity:	Less than 0.1 dB in absence of condensation

PREAMPLIFIER, BRUEL AND KJAER, MODEL 2619

Specifications

Gain:	1 : 1 (0.05 dB typical attenuation)
Frequency Response:	2 Hz - 200 kHz[1]
Input Impedance:	4000 megohms
Output Impedance:	25 ohms
Temperature Range:	-20 to +60° C
Output Signal:	1 volt rms to approximately 5 kHz (1500-ft. cable)
	0.1 volt rms to approximately 40 kHz (1500-ft. cable)
Polarizing Voltage:	+200 volts
Noise:	Less than 50 µV with 1/2-inch microphone
Distortion:	Less than 1% for normal operating conditions
Power:	120 Vdc, 28 Vdc

[1] The frequency response cited is the maximum obtainable for the preamplifier only. In the system configuration, the low frequency response is effectively controlled by source (microphone) capacitance and the high frequency response is a function of signal amplitude and output cable capacitance.

POWER SUPPLY, BRUEL AND KJAER, MODEL 2804

Specifications

Outputs:	Polarization voltage 200 volts, power supply 120 Vdc and 28 Vdc, auxiliary 28 Vdc, heater 6 - 12 Vdc (external battery)
Battery Voltage:	3.5 volts to 5 volts
Battery Life when Driving 2619 Pre-amplifier:	Approximately 40 hours
Noise and Ripple:	Adds no additional noise to Model 2619 preamplifier
Gain (with custom line driver):	1 : 1
Cross-talk Attenuation:	Better than 100 dB to 20 kHz
Temperature Range:	0^{o} to $+40^{o}$ C
Maximum Relative Humidity:	95%
Custom Line Driver	
Output Impedance:	50 ohms
Output Level:	1 volt rms minimum
Frequency Response:	Flat to at least 10 kHz with 1500-ft. coaxial cable
Power:	9-volt battery, 4 mA current drain

SIGNAL CONDITIONER, BRUEL AND KJAER, MODEL 140

Specifications

Number of Channels:	Four (4)
Gain:	10 dB steps from -20 to +40
Frequency Response:	2 - 40 000 Hz $\pm$ 0.4 dB
Output Impedance:	25 ohms
Maximum Output Voltage:	7 volts rms
Power:	110 - 220 volts, 50 to 400 Hz

SOUND LEVEL METER, GENERAL RADIO, MODEL 1551-C

(Modified for Use as Amplifier)

Specifications

Frequency Response:	The A, B, and C weighting characteristics are those specified in ANSI Standard S1.4-1961 and IEC Publication 123, 1961. The (20 kHz) response characteristic affords flat response from 20 Hz to 20 kHz
Gain:	-20 to +80 dB. in 5-dB steps
Input Impedance:	25 megohms in parallel with 50 pF
Output Level:	Nominal output voltage for full-scale meter reading is 1.4 volts rms, open circuit
Output Impedance:	7000 ohms
Power:	Two, 1 1/2-volt (D) cells and one, 67 1/2-volt battery

MAGNETIC TAPE RECORDER, HONEYWELL, MODEL 5600

Specifications

Number of Channels:	7 or 14
Tape Speeds:	60, 30, 15, 7-1/2, 3-3/4, 1-7/8, and 15/16 ips
Tape Speed Accuracy:	0.15%
Power:	105 - 129 volts, 48-420 Hz
Operating Temperature Range:	0 - 50° C
Relative Humidity:	5 - 95% noncondensing

Flutter:

Tape Speed (ips)	Bandwidth (Hz)	Cumulative Flutter % P-P (2 Sigma)
60	0.2 -10,000	0.3
30	0.2 - 5,000	0.4
15	0.2 - 2,500	0.5
7-1/2	0.2 - 1,250	0.6
3-3/4	0.2 - 625	0.7
1-7/8	0.2 - 312	0.9
15/16	0.2 - 156	1.1

Direct Record/Reproduce

Dynamic Characteristics

Based on standard IRIG head configuration without an FM channel on an adjacent track, and with recommended iron oxide tapes. Capable of operation with chromium dioxide tapes.

Tape Speed (ips)	Bandwidth (Hz ± 3 dB)	RMS Signal/RMS Noise (dB filtered) *	(dB unfiltered)
60	300-300,000	32	30
30	150-150,000	32	30
15	100- 75,000	32	30
7-1/2	50- 37,500	30	28
3-3/4	50- 18,750	30	28
1-7/8	50- 9,300	28	26
15/16	50- 4,700	28	26

*Measured at the output of a bandpass filter having 18 dB/octave attenuation beyond bandwidth limits.

Specifications

Harmonic Distortion:	Normal record level set for 1% third harmonic distortion of a 1-kHz signal recorded at 60 ips
Input Level:	0.3 volt rms fixed at recorder input terminals, with gain trim adjustment
Input Impedance:	100 kohms resistive paralleled by 100 pF, unbalanced to ground
Output Level:	1.0 volt rms fixed into 10 kohms, with gain trim adjustment
Output Impedance:	Less than 100 ohms
Equalization:	Mounted on plug-in equalizer cards. Each reproduce amplifier accepts two equalizers with the correct one being selected by the speed control switch

FM Record/Reproduce (± 40% deviation)

Record Amplifier:	Incorporates nine center frequencies, selected by speed switch and shorting pin for mode selection. Bias recorded in mixed direct/FM systems
Reproduce Amplifier:	Accepts two center frequency/filter units, selectable by speed switch. Filters convertible from flat to transient response by pin change.

Dynamic Characteristics

S/N Ratio vs. Bandwidth

Tape Speed	Standard (Low Band)	Extended (Intermediate Band)	DX (Wideband Group 1)
60	46 (10 kHz)	44 (20 kHz)	42 (40 kHz)
30	45 (5 kHz)	43 (10 kHz)	41 (20 kHz)
15	44 (2.5 kHz)	43 (5 kHz)	40 (10 kHz)
7-1/2	43 (1.25 kHz)	41 (2.5 kHz)	39 (5 kHz)
3-3/4	42 (625 Hz)	40 (1.25 kHz)	38 (2.5 kHz)
1-7/8	40 (312 Hz)	38 (625 Hz)	36 (1.25 kHz)
15/16	40 (156 Hz)	36 (312 Hz)	34 (625 Hz)

MAGNETIC TAPE RECORDER, HONEYWELL, MODEL 5600 (continued)

Total Harmonic Distortion:	1.5% maximum
Linearity:	± 1% of full deviation from best straight line through zero
Drift:	1% of full deviation over 10 days and 10° C to 35° C ambient
Input Level:	1.0 volt rms fixed for ± 40% deviation with zero and gain trim adjustments
Input Impedance:	Nominal 20 kohms paralleled by 100 pF maximum unbalanced to ground
Output Level:	1.0 volt rms fixed into 10 kohms with zero and gain trim adjustments
Output Impedance:	100 ohms maximum

TIME CODE GENERATOR, SYSTRON-DONNER, MODEL 8120

Specifications

Time Base:	Crystal controlled oscillator with stability of $\pm$ 1 in 10^5 within 0 to 60°C and an aging rate of $\pm$ 1 part in 10^7/24 hours after 72 hours. Provisions included for use of an external 1-MHz time base
Display:	Six-digit in-line planar readout to indicate time of day or elapsed time in hours, minutes, and seconds (three additional digits if Days / ID Number option is included)
Code Format:	Modified IRIG B format in terms of hours, minutes, and seconds (Days / ID Number optional)
Modulated Code:	The modulated code is generated on a precise 1-kHz carrier with an adjustable amplitude from 0 to 10 volts peak-to-peak from a low impedance 15 mA peak source and an adjustable modulation ratio (mark-to-space) from 2 : 1 to 6 : 1. Connector is rear panel BNC type
DC Level Shift Code:	The dc level shift code is generated with an adjustable amplitude from 1 to + 10 volts into a 600-ohm load. Connector is rear panel BNC type
Pulse Rates:	Simultaneous rates of 1 PPS, 10 PPS, 100 PPS, and 1 KPPS are provided with leading edge "on time." Levels are 0 to +5 volts nominal from a 6-kohm source (TTL) compatible. Connector is Amphenol 57-40500 (mating connector supplied)
Parallel BCD Outputs:	Updated time is provided as twenty parallel BCD lines representing hours, minutes, and seconds (twelve additional lines for Days / ID Number or Milliseconds options)
Code:	8-4-2-1

TIME CODE GENERATOR, SYSTRON-DONNER, MODEL 8120 (continued)

Logic:	Binary "1" = 5 (± 0.5) volts, 6-kohm source Binary "0" = 0 (± 0.5) volts, 10 mA sink
Connector:	Amphenol 57-40500. Mating connector supplied
Environment:	0° C to 50° C at up to 95% relative humidity
Power:	115/230 volts (± 10%), 48 to 62 Hz

GALVANOMETER AMPLIFIER, BELL AND HOWELL, MODEL 1-172

Specifications

Number of Channels:	Six (6)
Gain:	Controlled by plug-in feedback network resistor boards
Frequency Response (ac position):	1 Hz to 10 kHz $\pm$ 3 dB
Input Impedance:	1 megohm, shunted by 45 pF
Input Configuration:	Single ended
Maximum Input Voltage:	400 Vdc or peak ac without damage
Ambient Temperature:	0 to 50° C
Linearity:	$\pm$ 0.25% of full scale from best straight line to $\pm$ 80 milliamperes or $\pm$ 6.8 volts from amplifier, whichever is less
Power:	105 to 125 volts, 60 Hz

OSCILLOGRAPH, BELL AND HOWELL, MODEL 5-124

Specifications

Data Channels:	Eighteen (18)
Galvanometer Model:	7 - 361
Frequency Response:	0 - 5000 Hz $\pm$ 5%
Optical Arm:	11.5 inches at zero deflection
Recording Media:	7-inch paper
Trace Width:	Less than 0.01 inch
Maximum Writing Speed:	50 000 inches per second
Record Speeds:	0.25, 1, 4, 16, and 64 ips
Power:	105 to 125 volts, 50/60 Hz

APPENDIX C

MANUFACTURERS' SPECIFICATIONS FOR ACOUSTIC CALIBRATION DEVICES

This appendix contains the manufacturers' specifications for the acoustic calibration devices used in this test program as described in appendix A. The specifications are presented in the following order:

1. Bruel and Kjaer Model 4220 pistonphone
2. Bruel and Kjaer Model 4142 microphone calibration apparatus
3. General Radio Model 1382 random noise generator

PISTONPHONE, BRUEL & KJAER, MODEL 4220

Specifications

Accuracy:	$\pm$ 0.2 dB
Sound Pressure Level:	124 dB (ref. 2 X 10^{-5} N/m^2)
Frequency:	250 Hz $\pm$ 1%
Distortion:	Less than 3%
Temperature Range:	0 to +60°C (including batteries)
Humidity:	Relative humidities of up to 100% will not influence the calibration
Power:	7 Mallory RM-3 (R) mercury cells

MICROPHONE CALIBRATION APPARATUS, BRUEL & KJAER, MODEL 4142

Specifications

The following specifications apply to the determination of microphone frequency response, using the Model UA0033 electrostatic actuator supplied with the calibration apparatus.

Frequency Range:	20 - 20,000 Hz
Accuracy:	$\pm$ 0.5 dB (estimate)
Polarization Voltage:	800 volts
Power:	115 volts, 60 Hz

RANDOM NOISE GENERATOR, GENERAL RADIO, MODEL 1382

Specifications

Spectrum: Either (a) white noise (constant energy per hertz bandwidth) ± 1 dB, 20 Hz to 25 kHz, with 3-dB points at approximately 10 Hz and 50 kHz; (b) pink noise (constant energy per octave bandwidth) ± 1 dB, 20 Hz to 20 kHz; or (c) ANSI noise, as specified in ANSI Standard S1.4-1961

Waveform:

Voltage	Gaussian Probability Density Function	Amplitude-Density Distribution of 1382
0	0.0796	0.0796 ± 0.005
$\pm\sigma$	0.0484	0.0484 ± 0.005
$\pm 2\sigma$	0.0108	0.0108 ± 0.003
$\pm 3\sigma$	0.000898	0.000898 ± 0.0002
$\pm 4\sigma$	0.0000274	0.0000274 ± 0.00002

These data measured in a "window" of 0.2 σ, centered on the indicated values, σ is the standard deviation or rms value of the noise voltage.

Output Voltage: Greater than 3 volts rms maximum, open-circuit for any bandwidth

Output Impedance: 600 ohms

Amplitude Control: Continuous adjustment from full output to approximately 60 dB below that level

Power Required: 100 to 125 volts, 50 to 400 Hz

APPENDIX D

DATA ANALYSIS PROCEDURES

This appendix is intended to give the reader insight into NASA's method of applying the analysis procedure of reference 4 to the refan and hardwall DC-9 flyover noise data.

System Corrections

Prior to any analysis, the following system corrections were determined for each microphone channel:

1. Microphone response
2. Windscreen
3. Free field
4. Pink noise
5. Barometric pressure

Correction 1 was determined by a laboratory electrostatic microphone correction prior to the test. Corrections 2 and 3 were obtained from manufacturers' data and are shown in figure D1. Correction 4 was determined from daily system pre- or postcalibrations. And correction 5 was determined from measurements of the barometric pressure made prior to each series of test runs. Manufacturer's charts then provided a single number correction to the pistonphone calibration levels (see appendix A) to be applied to all 1/3 octave bands. Table D1 shows typical values for corrections 1-5.

In addition to these system corrections, a slow meter response was simulated by applying a running linear average over 1.5 sec to the levels

in each 1/3 octave band. To apply this method a 1/3 octave band spectrum was generated every 0.5 sec. Three consecutive 0.5 sec spectra were then averaged on a power basis and the result was associated with the time of the third 0.5 sec spectrum. The values in the first 0.5 sec spectrum were then dropped and the next three 0.5 spectra were averaged. This averaging procedure was repeated for the entire flight.

Ambient Noise Correction

When the flyover noise SPL, in any 1/3 octave band was within 5 to 10 dB of the ambient noise levels, the ambient noise was subtracted from the flyover noise on a power basis. The SPL of this difference then replaced the original 1/3 octave band level. If the flyover noise levels in a 1/3 octave band were 5 dB or closer to the ambient level, the level in that band was unchanged. These ambient corrected 1/3 octave band levels were then used in the PNL and PNLT calculations, with the exception that the bands whose levels were 5 dB or closer to the ambient were omitted from the PNL calculation.

Pseudotone Correction

To avoid calculating erroneous tone corrections because of ground reflections (pseudotones), the tone correction procedure of reference 4 was not applied to 1/3 octave bands up to and including the 800 Hz center frequency band.

Duration Factor

The time period d used to calculate the dnuation factor D specified in reference 4 was the interval, rounded to the nearest second, during which the criteria $PNLTM-PNLT \leq 10$ PNdB and $90 \text{ PNdB} \leq PNLT$ were satisfied. For the case of a two-peaked PNLT time history, the duration time was taken from the first point that met the criterion to the last point which met the criteria, rounded to the nearest second. When these criteria were satisfied, then

$$EPNL = PNLTM + D \tag{D1}$$

The equation for D given in reference 4 is

$$D = 10 \log \left[\sum_{k=o}^{2d} \log^{-1} (PNLT(k)/10) \right] - PNLTM - 13 \tag{D2}$$

Thus, substituting in D1

$$EPNL = 10 \log \left[\sum_{k=o}^{2d} \log^{-1} (PNLT(k)/10) \right] - 13 \tag{D3}$$

Reference 4 implies that when PNLTM-10 PNdB is 90 PNdB or less, the value of d should be taken as the time interval between the initial and final times for which $PNLT(k)$ equals 90 PNdB in the limiting case where $PNLTM = 90$ PNdB and $d = 0$, equation D3 becomes

$$EPNL = 10 \log \left[\log^{-1} (9) \right] - 13 = 77 \text{ EPNdB} \tag{D4}$$

Reference 4 provides no specific instructions for the case where $PNLTM < 90$ PNdB. To drop the summation in equation D3 would be an unsuitable solution in this case for then the EPNL would equal

- 13 EPNdB. One solution in this case might be

$$\text{EPNL} = \begin{cases} 10 \log \left[\sum_{k=o}^{2d} \log^{-1} (\text{PNLT}(k)/10) \right] - 13 \quad \text{for} \\ \qquad \text{PNLTM} \geq 90 \text{ PNdB} \\ \text{PNLTM} - 13 \text{ for PNLTM} < 90 \text{ PNdB} \end{cases} \tag{D5}$$

The approach taken in the analyses of this paper, however, was to set $D = 0$ when PNLTM < 90 PNdB. That is,

$$\text{EPNL} = \begin{cases} 10 \log \left[\sum_{k=0}^{2d} \log^{-1} (\text{PNLT}(k)/10) \right] - 13 \text{ for} \\ \qquad \text{PNLTM} \geq 90 \text{ PNdB} \\ \text{PNLTM for PNLTM} < 90 \text{ PNdB} \end{cases} \tag{D6}$$

As was shown in the discussion associated with figures 9 and 10, a small change in the PNLT time history from values greater than 90 PNdB to values slightly less than 90 PNdB can cause a large change in the calculated EPNL when equation D6 is used.

It can also be shown that equation D5 is sensitive PNLTM levels near 90 PNdB. In fact, for the cases associated with figures 9 and 10 a 10.3 EPNdB difference in levels would have resulted if equation D5 had been used (equation D6 gave a 2.7 EPNdB difference in levels).

An alternate solution to this anomaly would be to simply remove the 90 PNdB limit on the 10 dB down points and calculate the EPNL according to equation D3 as suggested in reference 8.

Duration Correction

Duration corrections were applied to the EPNL values whenever the actual and reference takeoff or landing approach flightpaths differed from one another. The correction term Δ_2 was calculated as follows

$$\Delta_2 = -10 \log \left(\frac{\Delta_a}{\Delta_r} \right) \text{ EPNdB} \tag{D7}$$

and was added algebraically to the EPNL calculated from the measured acoustic data. The section in this appendix titled "Flightpath Corrections" describes how the actual and reference distances of closest approach (Δ_a and Δ_r, respectively) are calculated.

Weather and Path Atmospheric Absorption Corrections

The acoustic spectrum at the time of PNLTM was corrected to the reference conditions of 25°C (77°F) and 70 percent relative humidity based on 10 m weather data. This was to account for differences in atmospheric sound absorption from the actual to reference weather conditions. The procedure was to correct each 1/3 octave band according to the following equation from reference 4.

$$\begin{aligned} SPL_{ic} &= SPL_{ia} + (\alpha_{ia} - \alpha_{ir})\, SR_a \\ &+ \alpha_{ir} (SR_a - SR_r) \\ &+ 20 \log (SR_a/SR_r) \end{aligned} \tag{D8}$$

where the SPL_{ia} and SPL_{ic} are the actual and corrected sound pressure levels, respectively, in the i th 1/3 octave band. The first correction

term accounts for the effects of change in atmospheric sound absorption for the entire actual propagation path (slant range) SR_a. The coefficients α_{ia} and α_{ir} are the sound absorption coefficients for the actual and reference atmospheric conditions, respectively, for the i th 1/3 octave band. The second correction term accounts for the excess, or shortage, of atmospheric absorption on the change in path from the actual to the reference slant range SR_r. The third correction term accounts for the effects of the inverse square law when correcting from the actual to reference slant range.

In these analyses the atmospheric absorption corrections were broken down into path and weather corrections. The sum of all the atmospheric absorption corrections of equation D8 on a PNLT basis was termed the "weather-plus-path correction." From the weather-plus-path corrected PNLT was subtracted the contribution of the $(\alpha_{ia} - \alpha_{ir})\ SR_a$ (weather correction) term. The result of this subtraction was termed the "path correction." The weather and path corrections for all the analyzed data points are displayed in tables 6, 7, and 8.

Flightpath Corrections

Flightpath data (flightpath angle, altitude over the microphone, lateral flightpath deviation, path speed, and time over the microphone) provided by DACO were used to geometrically calculate the actual and reference slant ranges at PNLTM and the actual and reference distances of closest approach. This section describes the method used to calculate the slant ranges and distances of closest approach.

Figure D2 shows a general test situation where actual and reference flightpath and measurement positions are known. It is assumed that

the values of A_a, A_r, L_a, L_r, V, t_m, t_o, γ_a, γ_r, and C are known. It is also assumed that the aircraft sound propagates in a straight line (i.e., refraction effects are ignored). The problem, then, is to compute the actual and reference slant ranges (SR_a and SR_r, respectively) and distances of closest approach (Δ_a and Δ_r, respectively). It can be shown that

$$SR_a = \sqrt{(L_a{}^2 + f^2) + (A_a + f \tan \gamma_a)^2} \tag{D9}$$

where f is the appropriate root of the quadratic equation

$$f^2 + f \frac{\left[2 A_a \tan \gamma_a + \frac{2 (t_m - t_o) V \cos \gamma_a}{k^2 \cos^2 \gamma_a}\right]}{\left[1 + \tan^2 \gamma_a - \frac{1}{k^2 \cos^2 \gamma_a}\right]} + \frac{\left[L_a{}^2 + A_a{}^2 - \frac{(t_m - t_o)^2 V^2 \cos^2 \gamma_a}{k^2 \cos^2 \gamma_a}\right]}{\left[1 + \tan^2 \gamma_a - \frac{1}{k^2 \cos^2 \gamma_a}\right]} = 0 . \tag{D10}$$

and where $k = \frac{V}{C}$.

Having computed the actual slant range, Δ_r, Δ_a, and SR_r may be computed as follows

$$\Delta_r = \sqrt{b_r{}^2 + L_r{}^2} \tag{D11}$$

where

$$b_r = A_r \cos \gamma_r \tag{D12}$$

Similarly,

$$\Delta_a = \sqrt{b_a^2 + L_a^2} \tag{D13}$$

where

$$b_a = A_a \cos \gamma_a \tag{D14}$$

The assumption is now made that α_a (the angle between the measurement position, the aircraft position when PNLTM was emitted, and the aircraft flight track) is the same for both the actual and reference measurement positions. Thus

$$\alpha_a = \alpha_r = \sin^{-1}\left(\frac{\Delta_a}{SR_a}\right) \tag{D15}$$

so that

$$SR_r = \frac{\Delta_r}{\sin \alpha_r} = \left(\frac{\Delta_r}{\Delta_a}\right) SR_a \tag{D16}$$

These values of SR_a, SR_r, Δ_a, and Δ_r were then used in the weather, path, and duration correction calculations.

Spectrum Shaping

Because preemphasis networks were not used in measuring the flyover noise, the weather-plus-path corrected 1/3 octave band spectra were allowed to roll off at a rate of 2 dB per 1/3 octave, beginning with the first 1/3 octave band (in the uncorrected spectrum) after the spectrum

peak which fell to within 4 dB of the ambient level. This procedure was used to avoid the calculation of erroneous tone corrections caused by large weather-plus-path corrections being applied to ambient spectrum levels.

Speed Correction

The following relationship, after reference 6, was used to correct the EPNL levels for differences between the actual and reference aircraft path speeds:

$$SC = 10 \log_{10} \left(\frac{V_a}{V_r} \right) \tag{D17}$$

TABEL D1

TYPICAL SYSTEM CORRECTIONS

1/3 OCTAVE BAND CENTER FREQUENCY Hz	CORRECTION AND VALUE, dB				
	WINDSCREEN*	FREE FIELD*	MIC RESPONSE	PINK NOISE	BAROMETRIC PRESSURE
50	0	0	0	-0.04	0.2
63	0	0	0	-0.02	0.2
80	0	0	0	-0.33	0.2
100	0	0	0	-0.69	0.2
125	0	0	0	+0.55	0.2
160	0	0	0	-0.14	0.2
200	0	0	0	-0.47	0.2
250	0	0	0	0	0.2
315	0	0	0	+0.22	0.2
400	0	0	0	+0.11	0.2
500	-0.10	+0.10	0	+0.12	0.2
630	-0.10	+0.10	0	0	0.2
800	-0.10	+0.10	-0.10	+0.60	0.2
1000	-0.13	+0.10	-0.10	+0.27	0.2
1250	-0.29	+0.11	-0.10	-0.05	0.2
1600	-0.49	+0.13	-0.10	-0.10	0.2
2000	-0.66	+0.15	-0.10	+0.16	0.2
2500	-0.84	+0.17	-0.10	-0.26	0.2
3150	-0.80	+0.19	-0.10	-0.51	0.2
4000	-0.23	+0.21	-0.10	+0.01	0.2
5000	+0.46	+0.23	-0.10	-0.31	0.2
6300	+0.47	+0.25	-0.15	+0.54	0.2
8000	+0.27	+0.27	-0.25	+0.32	0.2
10000	+0.99	+0.33	-0.45	+0.56	0.2

*For 90° incidence

COMPOSITE CORRECTION VALUES

INCIDENCE PLUS WINDSCREEN - 90°

1/3 octave band center frequency	Correction
1,000	-0.03
1,250	-0.18
1,600	-0.36
2,000	-0.51
2,500	-0.67
3,150	-0.61
4,000	-0.02
5,000	+0.69
6,300	+0.72
8,000	+0.55
10,000	+1.32
12,500	+1.53
16,000	+2.5

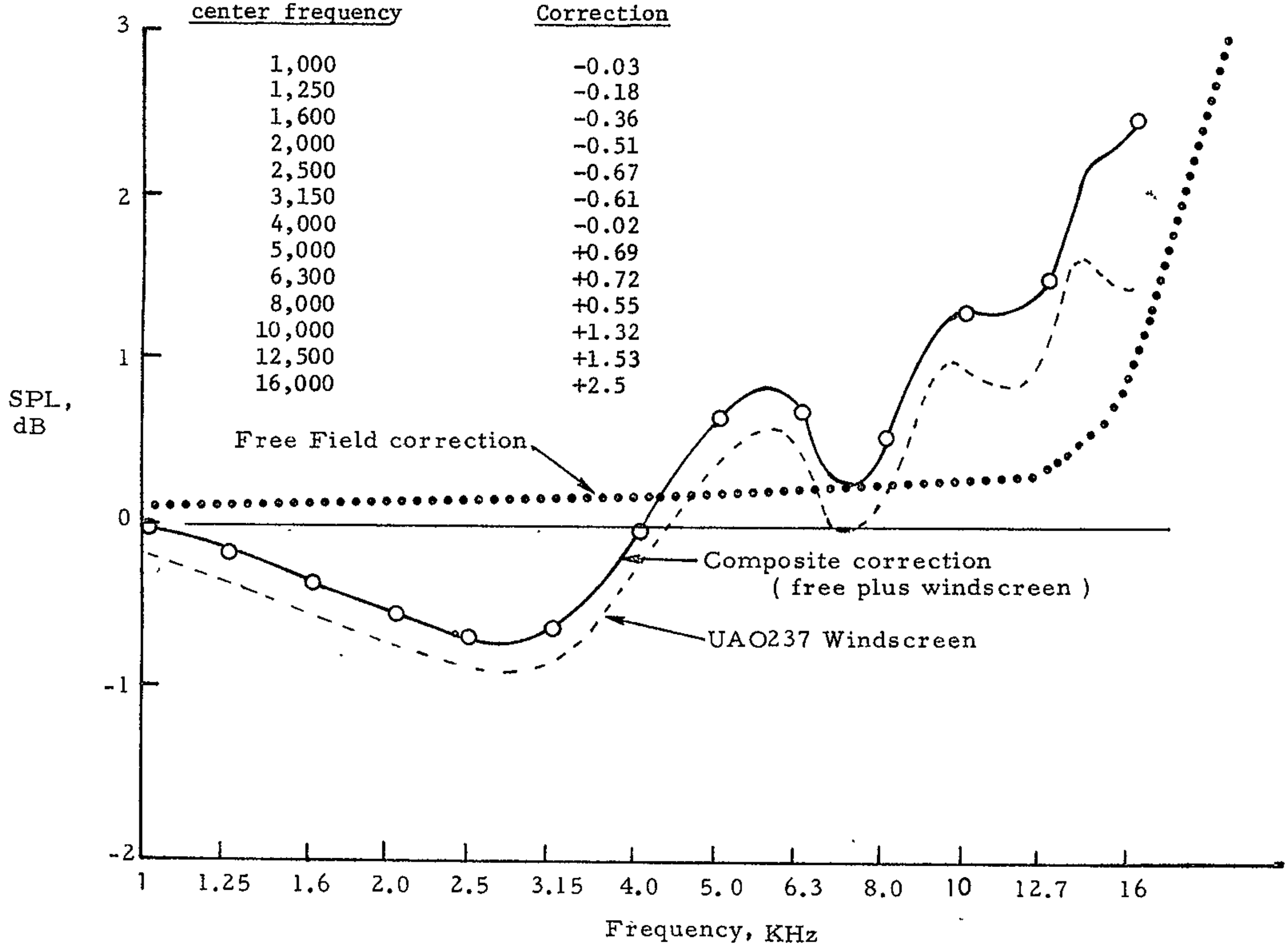


Figure D 1 - Composite, windscreen, and free field system corrections for 1.27 cm (1/2 in.) B & K microphone and 90° (grazing) incidence.

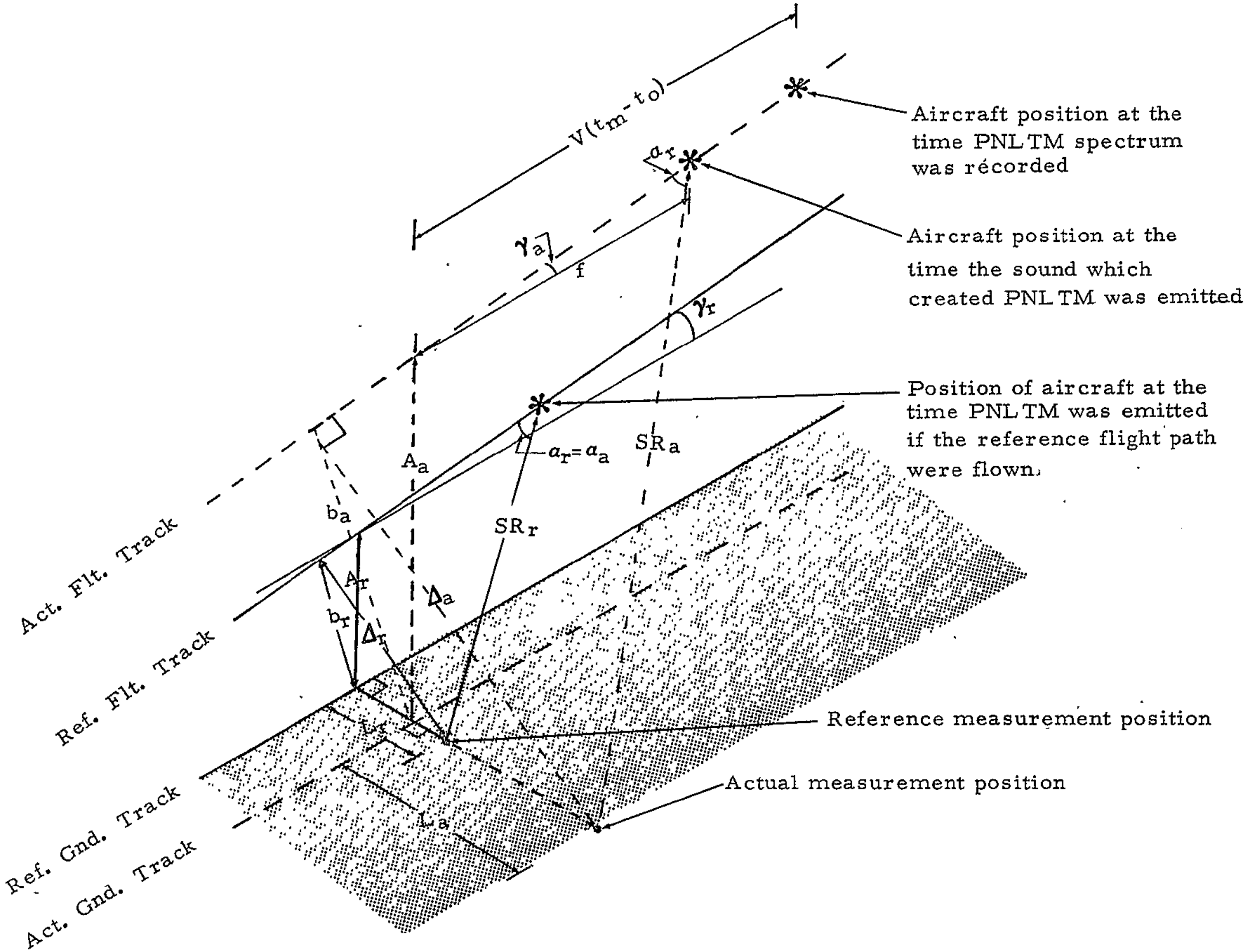


Figure D 2. - General test geometry for reference and actual test conditions.

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TABLE 1

COMPARISON OF NASA AND DACO-MEASURED FLYOVER NOISE LEVELS

FROM SYSTEMS COMPARISON TEST AS ANALYZED* BY DACO

	NASA		DACO		Δ
	NASA MIC 3	NASA MIC 4	DACO MIC 2	DACO MIC 5	($DACO_{AVE}$ - $NASA_{AVE}$)
dBA	95.7	95.4	95.4	95.8	+0.0
PNLM	110.3	109.8	109.8	110.4	+0.0
PNLTM	111.5	111.3	110.4	111.4	-0.5
Tone Correction	1.2	1.5	1.2	1.0	-0.2
Duration Factor	-6.4	-6.0	-5.8	-6.3	+0.2
EPNL	105.1	105.3	104.6	105.1	-0.4

*Using DACO pistonphone and pink noise calibations. Includes pink noise, slow response, windscreen, and microphone response corrections.

TABLE 2

COMPARISON OF NASA-MEASURED FLYOVER NOISE LEVELS

FROM SYSTEMS COMPARISON TEST AS ANALYZED* BY BOTH NASA AND DACO

	NASA ANALYSIS		DACO ANALYSIS		Δ
	NASA MIC 3	NASA MIC 4	DACO MIC 2	DACO MIC 5	($DACO_{AVE}$ - $NASA_{AVE}$)
dBA	95.7	95.3	95.7	95.4	+0.0
PNLM	110.4	109.9	110.3	109.8	-0.1
PNLTM	111.8	111.1	111.5	111.3	-0.0
Tone Correction	1.4	1.2	1.2	1.5	+0.0
Duration Factor	-7.1	-6.5	-6.4	-6.0	+0.6
EPNL	104.7	104.6	105.1	105.3	+0.6

*Using DACO pistonphone and pink noise calibrations. Includes pink noise, slow response windscreen, and microphone response corrections.

TABLE 3

COMPARISON OF NASA-MEASURED FLYOVER NOISE LEVELS FROM SYSTEMS COMPARISON TEST

AS ANALYZED* BY NASA USING BOTH NASA AND DACO CALIBRATIONS

	NASA CALIBRATIONS		DACO CALIBRATIONS		Δ
	NASA MIC 3	NASA MIC 4	NASA MIC 3	NASA MIC 4	$(DACO_{AVE} - NASA_{AVE})$
dBA	96.0	95.3	95.7	95.3	-0.2
PNLM	110.7	110.0	110.4	109.9	-0.2
PNLTM	112.0	111.6	111.8	111.1	-0.4
Tone Correction	1.3	1.6	1.4	1.2	-0.2
Duration Factor	-6.8	-6.6	-7.1	-6.5	-0.1
EPNL	105.2	105.0	104.7	104.6	-0.4

*Includes pink noise, slow response, windscreen, and microphone response corrections.

TABLE 4

COMPARISON OF NASA-MEASURED FLYOVER NOISE SPECTRA FROM SYSTEMS COMPARISON TESTS AS ANALYZED* BY NASA AND DACO AT TIME OF PNLM

FREQUENCY	NASA MIC 3		NASA MIC 4		Δ
	DACO	NASA	DACO	NASA	($DACO_{AVE}$ - $NASA_{AVE}$)
50	74.0	71.9	74.9	73.5	+1.8
63	--	72.0	73.0	69.2	-2.4
80	72.2	72.2	72.8	72.5	+0.2
100	82.2	82.6	83.5	83.8	-0.4
125	86.2	84.8	86.5	85.7	-1.1
160	88.5	87.8	88.3	87.2	+0.9
200	87.1	83.4	87.8	82.9	+4.3
250	86.0	86.2	85.8	86.0	-0.2
315	89.2	88.8	89.3	89.9	-0.1
400	86.0	85.8	86.4	86.2	+0.2
500	86.0	85.6	87.1	85.8	+0.8
630	85.7	85.7	86.5	85.3	+0.6
800	84.8	84.8	85.3	85.3	+0.5
1000	83.3	83.2	83.6	83.1	+0.3
1250	83.4	83.5	83.1	83.1	-0.0
1600	83.0	82.9	81.9	81.8	+0.1
2000	82.7	82.6	81.7	81.8	0.0
2500	84.2	84.2	83.2	83.4	-0.1
3150	87.5	88.1	86.3	87.1	-0.7
4000	83.9	84.1	83.2	83.4	-0.2
5000	79.7	80.2	78.9	79.7	-0.6
6300	77.8	77.0	76.7	77.1	+0.2
8000	75.7	75.8	74.8	75.7	-0.5
10000	71.1	72.1	70.9	71.8	-1.0

*Using DAC pistonphone and pink noise calibrations. Includes pin noise, slow response, windscreen, and microphone response corrections.

TABLE 5

DESCRIPTION OF DATA ANALYZED FOR (a) THE REFAN I PORTION OF THE TEST PROGRAM AND (b) THE REFAN II-HARDWALL PORTION OF THE TEST PROGRAM

(a) REFAN I

CONDITION	DATE	DATA POINTS
Takeoff with cutback	January 29, 1975	2
Cutback Corrections	January 29, 1975	3
Takeoff Corrections	Febraury 2, 1975	5-covering power range
Landing approach	January 31, 1975	3
Landing approach corrections	January 31, 1975 and February 1, 1975	7-covering power range

(b) REFAN II-HARDWALL

CONDITION	DATE	DATA POINTS
Takeoff with cutback	March 3, 1975	3 - refan 3 - hardwall
Cutback corrections	March 4, 1975	4 - hardwall
Takeoff corrections	March 4, 1975	5 - hardwall covering power range
Landing approach	February 26, 1975	2 - refan 2 - hardwall
Landing approach corrections	February 25, 1975 and February 26, 1975	5 - hardwall covering power range

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Table 6a. - Summary of Refan I data analyses.

Metric System

	Takeoff correction					Cutback correction		
RUN NUMBER	54	56	60	61	62	21	22	23
OVERHEAD TIME	9:46: 6.2	10: 1:26.6	10:30:10.7	10:36:51.8	10:47:12.1	11:33:48.3	11:42:10.4	11:49:25.2
TIME OF PNLTM	9:46:15.0	10: 1:30.5	10:30:14.5	10:36:56.0	10:47:16.5	11:33:54.5	11:42:16.5	11:49:32.5
REFERENCE CONDITIONS								
ALTITUDE, M	781.2	781.2	781.2	781.2	781.2	706.5	706.5	706.5
LATERAL DISPLACEMENT, M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	9.2	9.2	9.2	9.2	9.2	4.7	4.7	4.7
CLOSEST APPROACH, M	771.2	771.2	771.2	771.2	771.2	704.1	704.1	704.1
PATH SPEED, M/SEC	93.0	93.0	93.0	93.0	93.0	92.7	92.7	92.7
NORMALIZED THRUST, N	63557.5	63557.5	63557.5	63557.5	63557.5	42131.5	42131.5	42131.5
SLANT RANGE, M	1112.9	838.7	827.8	842.2	844.3	810.4	828.3	887.5
TEMPERATURE, DEG. CENT.	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS								
ALTITUDE, M	645.3	630.0	656.1	650.5	674.9	731.4	674.6	667.2
LATERAL DISPLACEMENT, M	3.5	-62.5	46.8	-3.4	18.9	-34.1	-22.8	5.4
PATH ANGLE, DEG.	8.9	8.4	8.0	7.5	7.7	6.1	6.2	5.6
CLOSEST APPROACH, M	637.5	626.4	651.4	645.0	669.0	728.1	671.1	664.0
PATH SPEED, M/SEC	92.5	92.7	93.2	93.0	92.3	90.3	90.8	91.8
NORMALIZED THRUST, N	60764.1	57054.5	53829.7	49777.6	47873.8	40717.0	39734.0	40347.8
SLANT RANGE, M	919.9	681.2	699.1	704.4	732.4	838.0	789.4	836.9
TEMPERATURE, DEG. CENT.	12.9	13.4	14.1	14.7	15.1	13.6	13.7	13.8
RELATIVE HUMIDITY, PERCENT	42.5	44.8	43.6	39.6	39.7	27.5	27.4	25.8
UNCORRECTED LEVELS								
DURATION FACTOR, PNDB	-.2	-.8	-.8	-1.0	-2.3	0.0	-6.3	-8.4
TONE BAND, KHZ	1.0	0.0	0.0	4.0	0.0	4.0	4.0	5.0
TONE CORRECTION, PNDB	3.6	0.0	0.0	1.3	0.0	1.4	1.1	1.3
PNLTM, PNDB	100.4	98.2	96.0	94.8	93.4	88.1	90.7	90.1
EPNL, EPNDB	100.2	97.4	95.2	93.9	91.1	88.1	84.4	81.7
OASPL, DB	94.7	93.5	91.9	89.5	89.7	84.2	86.7	85.9
DBA, DB	86.7	87.3	85.4	82.5	82.4	76.3	79.4	76.6
CORRECTED LEVELS								
TONE BAND, KHZ	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WEATHER CORRECTION, EPNDB	.7	1.0	1.2	-.4	1.0	.7	1.0	4.7
PATH CORRECTION, EPNDB	-2.3	-2.6	-2.1	-2.2	-1.8	.4	-.6	-1.1
SPEED CORRECTION, EPNDB	-.0	-.0	.0	-.0	-.0	-.1	-.1	-.0
DURATION CORRECTION, EPNDB	.8	.9	.7	.8	.6	-.1	.2	.3
THRUST CORRECTION, EPNDB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PNLTM, PNDB	98.8	96.6	95.0	92.2	92.6	89.2	91.1	93.6
EPNL, EPNDB	99.4	96.6	94.6	92.0	90.8	88.9	85.0	85.4
OASPL, DB	92.5	91.2	90.0	87.5	88.1	84.4	86.2	85.5
DBA, DB	84.1	84.6	83.2	80.2	80.5	76.9	79.1	78.5

Table 6a - Continued.

Metric System

	Takeoff with cutback		Landing Approach Correction					
RUN NUMBER	12	19	33	35	37	39	40	41
OVERHEAD TIME	10: 3:53.4	11:17:51.5	11:20:20.4	11:37:33.9	11:50:58.7	9:32:13.0	9:40:14.3	9:48: 6.6
TIME OF PNLTM	10: 3:57.5	11:17:56.5	11:20:21.5	11:37:35.0	11:51: 0.0	9:32:15.0	9:40:16.5	9:48: 8.5
REFERENCE CONDITIONS								
ALTITUDE, M	706.5	706.5	112.8	112.8	112.8	112.8	112.8	112.8
LATERAL DISPLACEMENT, M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	4.7	4.7	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
CLOSEST APPROACH, M	704.1	704.1	112.6	112.6	112.6	112.6	112.6	112.6
PATH SPEED, M/SEC	92.7	92.7	72.8	72.8	72.8	72.8	72.8	72.8
NORMALIZED THRUST, N	42131.5	42131.5	23823.5	23823.5	23823.5	23823.5	23823.5	23823.5
SLANT RANGE, M	746.0	783.6	118.8	118.6	133.0	153.3	160.1	142.8
TEMPERATURE, DEG. CENT.	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS								
ALTITUDE, M	685.3	663.2	116.7	117.9	84.6	110.6	113.6	113.8
LATERAL DISPLACEMENT, M	-29.0	-13.2	-55.2	-58.9	-56.5	-49.4	-53.1	-56.9
PATH ANGLE, DEG.	5.2	5.8	-3.1	-2.9	-2.7	-3.4	-2.4	-3.1
CLOSEST APPROACH, M	683.1	659.9	128.9	131.7	101.7	120.9	125.3	127.1
PATH SPEED, M/SEC	90.2	89.9	70.8	71.2	71.5	78.1	78.5	73.8
NORMALIZED THRUST, N	41926.8	39805.2	19842.5	17671.9	14229.2	28645.1	30829.1	26990.5
SLANT RANGE, M	723.7	734.4	136.0	138.6	120.0	164.6	178.1	161.1
TEMPERATURE, DEG. CENT.	11.2	13.6	13.6	14.2	15.8	11.5	12.2	12.7
RELATIVE HUMIDITY, PERCENT	34.0	30.4	43.3	45.2	38.4	51.5	51.0	46.6
UNCORRECTED LEVELS								
DURATION FACTOR, PNDB	0.0	0.0	-5.5	-5.1	-6.0	-5.5	-5.5	-5.4
TONE BAND, KHZ	4.0	4.0	6.3	6.3	5.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	1.5	1.3	.7	.7	1.8	0.0	0.0	0.0
PNLTM, PNDB	89.1	89.2	100.5	99.7	101.4	104.2	105.2	103.2
EPNL, EPNDB	89.1	89.2	95.0	94.5	95.4	98.7	99.7	97.8
OASPL, DB	85.0	85.1	90.9	90.2	90.5	95.3	96.3	93.6
DBA, DB	78.4	77.5	87.3	86.6	87.3	91.1	92.0	90.1
CORRECTED LEVELS								
TONE BAND, KHZ	0.0	0.0	6.3	6.3	5.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	0.0	0.0	.6	.7	1.6	0.0	0.0	0.0
WEATHER CORRECTION, EPNDB	.6	.1	1.1	.7	1.7	1.1	1.1	1.1
PATH CORRECTION, EPNDB	-.4	-.7	1.4	1.6	-1.2	.8	1.2	1.3
SPEED CORRECTION, EPNDB	-.1	-.1	-.1	-.1	-.1	.3	.3	.1
DURATION CORRECTION, EPNDB	.1	.3	-.6	-.7	.4	-.3	-.5	-.5
THRUST CORRECTION, EPNDB	.1	1.5	0.0	0.0	0.0	0.0	0.0	0.0
PNLTM, PNDB	89.4	88.5	103.0	102.0	102.0	106.1	107.5	105.7
EPNL, EPNDB	89.5	90.1	96.8	96.1	96.4	100.6	101.8	99.8
OASPL, DB	84.6	84.3	92.4	91.7	89.9	96.0	97.4	95.0
DBA, DB	78.1	76.8	89.1	88.4	86.9	92.2	93.4	91.8

Table 6a. Concluded.

Metric System

	Landing Approach			
RUN NUMBER	51	27	28	32
OVERHEAD TIME	11:19:35.5	10:14:49.9	10:33:31.1	11:10:32.7
TIME OF PNLTM	11:19:37.5	10:14:51.0	10:33:32.0	11:10:34.0
REFERENCE CONDITIONS				
ALTITUDE, M	112.8	112.8	112.8	112.8
LATERAL DISPLACEMENT, M	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	-3.0	-3.0	-3.0	-3.0
CLOSEST APPROACH, M	112.6	112.6	112.6	112.6
PATH SPEED, M/SEC	72.8	72.8	72.8	72.8
NORMALIZED THRUST, N	23823.5	23823.5	23823.5	23823.5
SLANT RANGE, M	147.7	120.2	119.7	121.1
TEMPERATURE, DEG. CENT.	25.0	25.0	25.0	25.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS				
ALTITUDE, M	110.2	105.0	89.2	121.2
LATERAL DISPLACEMENT, M	-57.0	-59.0	-48.1	-61.4
PATH ANGLE, DEG.	-3.1	-3.1	-2.6	-3.6
CLOSEST APPROACH, M	123.9	120.3	101.3	135.7
PATH SPEED, M/SEC	73.0	69.9	69.3	70.5
NORMALIZED THRUST, N	24201.6	24495.1	22502.4	24539.6
SLANT RANGE, M	162.5	128.4	107.6	145.9
TEMPERATURE, DEG. CENT.	14.4	11.7	12.3	13.3
RELATIVE HUMIDITY, PERCENT	35.8	49.7	51.7	46.8
UNCORRECTED LEVELS				
DURATION FACTOR, PNDB	-5.3	-5.8	-6.0	-4.9
TONE BAND, KHZ	0.0	0.0	6.3	0.0
TONE CORRECTION, PNDB	0.0	0.0	.6	0.0
PNLTM, PNDB	101.3	103.7	104.2	101.6
EPNL, EPNDB	96.0	97.9	98.2	96.7
OASPL, DB	92.4	94.2	94.3	93.1
DBA, DB	88.6	90.4	90.6	89.0
CORRECTED LEVELS				
TONE BAND, KHZ	0.0	6.3	6.3	0.0
TONE CORRECTION, PNDB	0.0	.6	.5	0.0
WEATHER CORRECTION, EPNDB	1.7	1.4	.6	.9
PATH CORRECTION, EPNDB	1.1	.7	-1.1	2.0
SPEED CORRECTION, EPNDB	.0	-.2	-.2	-.1
DURATION CORRECTION, EPNDB	-.4	-.3	.5	-.8
THRUST CORRECTION, EPNDB	0.0	-.3	1.1	-.3
PNLTM, PNDB	104.1	105.8	103.7	104.5
EPNL, EPNDB	98.4	99.3	99.0	98.4
OASPL, DB	93.6	94.9	93.4	94.9
DBA, DB	90.4	91.4	89.8	91.1

Table 6b. - Summary of Refan I data analyses.

English System

	Takeoff correction					Cutback correction		
RUN NUMBER	54	56	60	61	62	21	22	23
OVERHEAD TIME	9:46: 6.2	10: 1:26.6	10:30:10.7	10:36:51.8	10:47:12.1	11:33:48.3	11:42:10.4	11:49:25.2
TIME OF PNLTM	9:46:15.0	10: 1:30.5	10:30:14.5	10:36:56.0	10:47:16.5	11:33:54.5	11:42:16.5	11:49:32.5
REFERENCE CONDITIONS								
ALTITUDE, FT	2563.0	2563.0	2563.0	2563.0	2563.0	2318.0	2318.0	2318.0
LATERAL DISPLACEMENT, FT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	9.2	9.2	9.2	9.2	9.2	4.7	4.7	4.7
CLOSEST APPROACH, FT	2530.3	2530.3	2530.3	2530.3	2530.3	2310.1	2310.1	2310.1
PATH SPEED, FT/SEC	305.1	305.1	305.1	305.1	305.1	304.0	304.0	304.0
NORMALIZED THRUST, LBF	14289.0	14289.0	14289.0	14289.0	14289.0	9472.0	9472.0	9472.0
SLANT RANGE, FT	3651.2	2751.8	2715.8	2763.3	2770.0	2658.8	2717.6	2911.7
TEMPERATURE, DEG. FAHR.	77.0	77.0	77.0	77.0	77.0	77.0	77.0	77.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS								
ALTITUDE, FT	2117.1	2066.9	2152.5	2134.3	2214.1	2399.6	2213.3	2189.0
LATERAL DISPLACEMENT, FT	11.6	-205.2	153.6	-11.0	62.1	-111.9	-74.9	17.8
PATH ANGLE, DEG.	8.9	8.4	8.0	7.5	7.7	6.1	6.2	5.6
CLOSEST APPROACH, FT	2091.6	2055.0	2137.1	2116.1	2195.0	2388.6	2201.6	2178.6
PATH SPEED, FT/SEC	303.5	304.2	305.9	305.0	302.7	296.2	297.8	301.3
NORMALIZED THRUST, LBF	13661.0	12827.0	12102.0	11191.0	10763.0	9154.0	8933.0	9071.0
SLANT RANGE, FT	3018.2	2234.8	2293.8	2310.9	2403.0	2749.2	2589.9	2745.9
TEMPERATURE, DEG. FAHR.	55.3	56.1	57.4	58.5	59.1	56.4	56.7	56.9
RELATIVE HUMIDITY, PERCENT	42.5	44.8	43.6	39.6	39.7	27.5	27.4	25.8
UNCORRECTED LEVELS								
DURATION FACTOR, PNDB	-.2	-.8	-.8	-1.0	-2.3	0.0	-6.3	-8.4
TONE BAND, KHZ	1.0	0.0	0.0	4.0	0.0	4.0	4.0	5.0
TONE CORRECTION, PNDB	3.6	0.0	0.0	1.3	0.0	1.4	1.1	1.3
PNLTM, PNDB	100.4	98.2	96.0	94.8	93.4	88.1	90.7	90.1
EPNL, EPNDB	100.2	97.4	95.2	93.9	91.1	88.1	84.4	81.7
OASPL, DB	94.7	93.5	91.9	89.5	89.7	84.2	86.7	85.9
DBA, DB	86.7	87.3	85.4	82.5	82.4	76.3	79.4	76.6
CORRECTED LEVELS								
TONE BAND, KHZ	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WEATHER CORRECTION, EPNDB	.7	1.0	1.2	-.4	1.0	.7	1.0	4.7
PATH CORRECTION, EPNDB	-2.3	-2.6	-2.1	-2.2	-1.8	.4	-.6	-1.1
SPEED CORRECTION, EPNDB	-.0	-.0	.0	-.0	-.0	-.1	-.1	-.0
DURATION CORRECTION, EPNDB	.8	.9	.7	.8	.6	-.1	.2	.3
THRUST CORRECTION, EPNDB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PNLTM, PNDB	98.8	96.6	95.0	92.2	92.6	89.2	91.1	93.6
EPNL, EPNDB	99.4	96.6	94.6	92.0	90.8	88.9	85.0	85.4
OASPL, DB	92.5	91.2	90.0	87.5	88.1	84.4	86.2	85.5
DBA, DB	84.1	84.6	83.2	80.2	80.5	76.9	79.1	78.5

Table 6b. - Continued.

Engl sh System

	Takeoff with cutback		Landing Approach correction					
RUN NUMBER	12	19	33	35	37	39	40	41
OVERHEAD TIME	10: 3:53.4	11:17:51.5	11:20:20.4	11:37:33.9	11:50:58.7	9:32:13.0	9:40:14.3	9:48: 6.6
TIME OF PNLTM	10: 3:57.5	11:17:56.5	11:20:21.5	11:37:35.0	11:51: 0.0	9:32:15.0	9:40:16.5	9:48: 8.5
REFERENCE CONDITIONS								
ALTITUDE, FT	2318.0	2318.0	370.0	370.0	370.0	370.0	370.0	370.0
LATERAL DISPLACEMENT, FT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	4.7	4.7	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
CLOSEST APPROACH, FT	2310.1	2310.1	369.5	369.5	369.5	369.5	369.5	369.5
PATH SPEED, FT/SEC	304.0	304.0	238.7	238.7	238.7	238.7	238.7	238.7
NORMALIZED THRUST, LBF	9472.0	9472.0	5356.0	5356.0	5356.0	5356.0	5356.0	5356.0
SLANT RANGE, FT	2447.5	2570.8	389.7	389.0	436.2	502.8	525.4	468.5
TEMPERATURE, DEG. FAHR.	77.0	77.0	77.0	77.0	77.0	77.0	77.0	77.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS								
ALTITUDE, FT	2248.4	2175.8	382.9	386.8	277.6	362.7	372.6	373.4
LATERAL DISPLACEMENT, FT	-95.1	-43.3	-181.0	-193.4	-185.4	-162.2	-174.1	-186.7
PATH ANGLE, DEG.	5.2	5.8	-3.1	-2.9	-2.7	-3.4	-2.4	-3.1
CLOSEST APPROACH, FT	2241.2	2165.1	423.0	432.0	333.6	396.7	411.0	417.0
PATH SPEED, FT/SEC	295.9	294.9	232.3	233.5	234.5	256.1	257.4	242.2
NORMALIZED THRUST, LBF	9426.0	8949.0	4461.0	3973.0	3199.0	6440.0	6931.0	6068.0
SLANT RANGE, FT	2374.4	2409.4	446.2	454.8	393.8	539.9	584.4	528.7
TEMPERATURE, DEG. FAHR.	52.1	56.5	56.5	57.5	60.5	52.7	53.9	54.9
RELATIVE HUMIDITY, PERCENT	34.0	30.4	43.3	45.2	38.4	51.5	51.0	46.6
UNCORRECTED LEVELS								
DURATION FACTOR, PNDB	0.0	0.0	-5.5	-5.1	-6.0	-5.5	-5.5	-5.4
TONE BAND, KHZ	4.0	4.0	6.3	6.3	5.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	1.5	1.3	.7	.7	1.8	0.0	0.0	0.0
PNLTM, PNDB	89.1	89.2	100.5	99.7	101.4	104.2	105.2	103.2
EPNL, EPNDB	89.1	89.2	95.0	94.5	95.4	98.7	99.7	97.8
OASPL, DB	85.0	85.1	90.9	90.2	90.5	95.3	96.3	93.6
DBA, DB	78.4	77.5	87.3	86.6	87.3	91.1	92.0	90.1
CORRECTED LEVELS								
TONE BAND, KHZ	0.0	0.0	6.3	6.3	5.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	0.0	0.0	.6	.7	1.6	0.0	0.0	0.0
WEATHER CORRECTION, EPNDB	.6	.1	1.1	.7	1.7	1.1	1.1	1.1
PATH CORRECTION, EPNDB	-.4	-.7	1.4	1.6	-1.2	.8	1.2	1.3
SPEED CORRECTION, EPNDB	-.1	-.1	-.1	-.1	-.1	.3	.3	.1
DURATION CORRECTION, EPNDB	.1	.3	-.6	-.7	.4	-.3	-.5	-.5
THRUST CORRECTION, EPNDB	.1	1.5	0.0	0.0	0.0	0.0	0.0	0.0
PNLTM, PNDB	89.4	88.5	103.0	102.0	102.0	106.1	107.5	105.7
EPNL, EPNDB	89.5	90.1	96.8	96.1	96.4	100.6	101.8	99.8
OASPL, DB	84.6	84.3	92.4	91.7	89.9	96.0	97.4	95.0
DBA, DB	78.1	76.8	89.1	88.4	86.9	92.2	93.4	91.8

Table 6b - Concluded.

English System

		Landing Approach		
RUN NUMBER	51	27	28	32
OVERHEAD TIME	11:19:35.5	10:14:49.9	10:33:31.1	11:10:32.7
TIME OF PNLTM	11:19:37.5	10:14:51.0	10:33:32.0	11:10:34.0
REFERENCE CONDITIONS				
ALTITUDE, FT	370.0	370.0	370.0	370.0
LATERAL DISPLACEMENT, FT	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	-3.0	-3.0	-3.0	-3.0
CLOSEST APPROACH, FT	369.5	369.5	369.5	369.5
PATH SPEED, FT/SEC	238.7	238.7	238.7	238.7
NORMALIZED THRUST, LBF	5356.0	5356.0	5356.0	5356.0
SLANT RANGE, FT	484.7	394.2	392.6	397.5
TEMPERATURE, DEG. FAHR.	77.0	77.0	77.0	77.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS				
ALTITUDE, FT	361.5	344.5	297.8	397.7
LATERAL DISPLACEMENT, FT	-186.9	-193.7	-157.8	-201.5
PATH ANGLE, DEG.	-3.1	-3.1	-2.6	-3.6
CLOSEST APPROACH, FT	406.5	394.8	332.3	445.1
PATH SPEED, FT/SEC	239.5	229.4	227.5	231.4
NORMALIZED THRUST, LBF	5441.0	5507.0	5059.0	5517.0
SLANT RANGE, FT	533.2	421.2	353.1	478.8
TEMPERATURE, DEG. FAHR.	58.0	53.1	54.1	56.0
RELATIVE HUMIDITY, PERCENT	35.8	49.7	51.7	46.8
UNCORRECTED LEVELS				
DURATION FACTOR, PNDB	-5.3	-5.8	-6.0	-4.9
TONE BAND, KHZ	0.0	0.0	6.3	0.0
TONE CORRECTION, PNDB	0.0	0.0	.6	0.0
PNLTM, PNDB	101.3	103.7	104.2	101.6
EPNL, EPNDB	96.0	97.9	98.2	96.7
OASPL, DB	92.4	94.2	94.3	93.1
DBA, DB	88.6	90.4	90.6	89.0
CORRECTED LEVELS				
TONE BAND, KHZ	0.0	6.3	6.3	0.0
TONE CORRECTION, PNDB	0.0	.6	.5	0.0
WEATHER CORRECTION, EPNDB	1.7	1.4	.6	.9
PATH CORRECTION, EPNDB	1.1	.7	-1.1	2.0
SPEED CORRECTION, EPNDB	.0	-.2	-.2	-.1
DURATION CORRECTION, EPNDB	-.4	-.3	.5	-.8
THRUST CORRECTION, EPNDB	0.0	-.3	1.1	-.3
PNLTM, PNDB	104.1	105.8	103.7	104.5
EPNL, EPNDB	98.4	99.3	99.0	98.4
OASPL, DB	93.6	94.9	93.4	94.9
DBA, DB	90.4	91.4	89.8	91.1

Table 7a. - Summary of hardwall data analyses.

Metric System

	Takeoff correction					Cutback correction		
RUN NUMBER	37	38	43	45	47	39	40	41
OVERHEAD TIME	4:59:10.8	5:11:32.9	5:54:41.7	6:10:57.5	6:27:17.3	5:20: 2.7	5:28:24.2	5:36:57.2
TIME OF PNLTM	4:59:14.0	5:11:36.5	5:54:47.5	6:11: 1.5	6:27:21.0	5:20: 6.5	5:28:29.0	5:37: 2.0
REFERENCE CONDITIONS								
ALTITUDE, M	654.4	654.4	654.4	654.4	654.4	597.1	597.1	597.1
LATERAL DISPLACEMENT, M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	8.1	8.1	8.1	8.1	8.1	4.4	4.4	4.4
CLOSEST APPROACH, M	647.9	647.9	647.9	647.9	647.9	595.4	595.4	595.4
PATH SPEED, M/SEC	91.9	91.9	91.9	91.9	91.9	92.4	92.4	92.4
NORMALIZED THRUST, N	57343.6	57343.6	57343.6	57343.6	57343.6	40063.1	40063.1	40063.1
SLANT RANGE, M	735.0	715.1	861.8	720.8	700.6	675.9	705.7	704.0
TEMPERATURE, DEG. CENT.	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS								
ALTITUDE, M	413.5	524.4	487.1	507.3	521.4	468.5	516.3	520.3
LATERAL DISPLACEMENT, M	-90.2	-122.1	-50.0	-45.0	-74.5	-69.7	-30.7	-60.5
PATH ANGLE, DEG.	6.6	7.1	6.5	2.9	2.2	4.5	4.1	4.2
CLOSEST APPROACH, M	420.5	534.5	486.6	508.6	526.3	472.2	515.9	522.4
PATH SPEED, M/SEC	98.8	98.9	95.0	94.7	96.6	97.4	96.9	97.4
NORMALIZED THRUST, N	49448.4	56934.4	47469.1	36687.1	31020.4	40752.6	40988.3	40899.4
SLANT RANGE, M	477.1	589.9	647.2	565.9	569.1	536.1	611.6	617.7
TEMPERATURE, DEG. CENT.	14.6	15.4	18.3	18.4	16.7	15.6	16.1	17.2
RELATIVE HUMIDITY, PERCENT	26.0	28.7	15.8	12.8	16.6	21.6	19.3	17.4
UNCORRECTED LEVELS								
DURATION FACTOR, PNDB	-1.8	-.4	-.3	-1.4	-3.9	-1.7	-1.0	-1.5
TONE BAND, KHZ	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
TONE CORRECTION, PNDB	2.5	2.6	2.3	2.4	2.3	2.6	2.5	2.3
PNLTM, PNDB	105.0	104.6	101.1	95.6	92.5	99.2	97.7	97.7
EPNL, EPNDB	103.2	104.2	100.8	94.2	88.6	97.5	96.7	96.2
OASPL, DB	98.9	98.8	97.2	90.1	87.2	93.8	92.2	93.1
DBA, DB	93.0	92.6	88.0	83.8	81.1	86.5	84.9	84.9
CORRECTED LEVELS								
TONE BAND, KHZ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WEATHER CORRECTION, EPNDB	-.8	-.6	.0	1.7	1.0	-.5	-.0	.3
PATH CORRECTION, EPNDB	-4.8	-2.2	-3.1	-2.8	-2.4	-2.6	-1.6	-1.5
SPEED CORRECTION, EPNDB	.3	.3	.1	.1	.2	.2	.2	.2
DURATION CORRECTION, EPNDB	1.9	.8	1.2	1.1	.9	1.0	.6	.6
THRUST CORRECTION, EPNDB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PNLTM, PNDB	99.4	101.9	98.0	94.5	91.1	96.2	96.0	96.6
EPNL, EPNDB	99.8	102.6	99.0	94.3	88.3	95.8	95.9	95.8
OASPL, DB	94.6	96.7	94.6	88.4	85.5	91.6	90.9	92.0
DBA, DB	88.6	90.5	85.6	83.1	80.0	84.5	84.0	84.2

Table 7a. - Continued.

Metric System

		Takeoff with cutback			Landing Approach correction			
RUN NUMBER	42	29	31	36	3	4	11	12
OVERHEAD TIME	5:45:24.7	8: 9:41.6	8:30:12.0	9:19:11.9	10:11:43.9	10:20: 8.3	11:21:37.1	11:30:30.2
TIME OF PNLTM	5:45:29.0	8: 9:44.0	8:30:15.5	9:19:16.0	10:11:46.5	10:20:10.5	11:21:39.5	11:30:32.0
REFERENCE CONDITIONS								
ALTITUDE, M	597.1	597.1	597.1	597.1	112.8	112.8	112.8	112.8
LATERAL DISPLACEMENT, M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	4.4	4.4	4.4	4.4	-3.0	-3.0	-3.0	-3.0
CLOSEST APPROACH, M	595.4	595.4	595.4	595.4	112.6	112.6	112.6	112.6
PATH SPEED, M/SEC	92.4	92.4	92.4	92.4	73.4	73.4	73.4	73.4
NORMALIZED THRUST, N	40063.1	40063.1	40063.1	40063.1	24148.2	24148.2	24148.2	24148.2
SLANT RANGE, M	678.3	627.6	657.6	669.6	173.9	153.7	160.4	136.7
TEMPERATURE, DEG. CENT.	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS								
ALTITUDE, M	518.0	401.1	484.1	533.5	113.2	122.3	118.1	118.5
LATERAL DISPLACEMENT, M	39.8	-97.5	-7.7	-97.0	-69.3	-49.7	-50.4	-62.0
PATH ANGLE, DEG.	3.9	3.6	3.5	4.6	-3.3	-3.5	-3.8	-3.3
CLOSEST APPROACH, M	518.4	412.0	483.3	540.6	132.6	131.9	128.2	133.5
PATH SPEED, M/SEC	96.2	100.1	102.0	101.2	81.1	77.5	73.9	74.4
NORMALIZED THRUST, N	40699.2	40490.1	41224.1	40814.8	27039.4	25647.2	21386.0	20091.6
SLANT RANGE, M	590.6	434.3	533.8	608.0	204.7	179.9	182.6	162.1
TEMPERATURE, DEG. CENT.	17.6	13.3	14.7	18.9	18.9	18.3	16.4	16.2
RELATIVE HUMIDITY, PERCENT	16.9	36.1	31.1	28.3	28.5	30.1	35.5	36.0
UNCORRECTED LEVELS								
DURATION FACTOR, PNDB	-1.2	-1.7	-1.3	-1.0	-5.2	-4.8	-5.0	-4.4
TONE BAND, KHZ	4.0	10.0	4.0	4.0	2.5	2.5	4.0	4.0
TONE CORRECTION, PNDB	2.6	.7	1.9	2.5	1.2	1.0	1.3	1.1
PNLTM, PNDB	97.8	99.9	99.4	98.2	111.7	110.1	108.6	107.7
EPNL, EPNDB	96.5	98.2	98.1	97.2	106.5	105.2	103.6	103.3
OASPL, DB	92.5	94.1	93.0	92.2	99.8	97.6	95.7	94.2
DBA, DB	84.6	89.6	87.0	86.2	96.6	95.0	92.9	92.2
CORRECTED LEVELS								
TONE BAND, KHZ	0.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0
TONE CORRECTION, PNDB	0.0	0.0	0.0	0.0	1.4	1.1	1.4	1.2
WEATHER CORRECTION, EPNDB	.1	1.5	.2	-.1	3.5	3.2	3.1	2.8
PATH CORRECTION, EPNDB	-1.6	-4.5	-2.5	-1.1	2.0	1.9	1.6	2.0
SPEED CORRECTION, EPNDB	.2	.3	.4	.4	.4	.2	.0	.1
DURATION CORRECTION, EPNDB	.6	1.6	.9	.4	-.7	-.7	-.6	-.7
THRUST CORRECTION, EPNDB	0.0	-.2	-.6	-.4	0.0	0.0	0.0	0.0
PNLTM, PNDB	96.3	96.9	97.1	97.0	117.3	115.1	113.3	112.5
EPNL, EPNDB	95.9	97.0	96.5	96.4	111.8	109.8	107.7	107.4
OASPL, DB	91.3	90.4	90.9	91.2	102.6	100.4	98.1	97.2
DBA, DB	84.0	85.7	84.9	85.2	100.7	98.9	96.5	96.1

Table 7a. - Concluded.

Metric System

	← →	← Landing Approach	→
RUN NUMBER	13	5	10
OVERHEAD TIME	11:38:35.8	10:28:20.7	11:12:48.5
TIME OF PNLTM	11:38:38.0	10:28:23.0	11:12:50.5
REFERENCE CONDITIONS			
ALTITUDE, M	112.8	112.8	112.8
LATERAL DISPLACEMENT, M	0.0	0.0	0.0
PATH ANGLE, DEG.	-3.0	-3.0	-3.0
CLOSEST APPROACH, M	112.6	112.6	112.6
PATH SPEED, M/SEC	73.4	73.4	73.4
NORMALIZED THRUST, N	24148.2	24148.2	24148.2
SLANT RANGE, M	152.7	146.4	147.3
TEMPERATURE, DEG. CENT.	25.0	25.0	25.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0
ACTUAL CONDITIONS			
ALTITUDE, M	110.6	126.6	111.1
LATERAL DISPLACEMENT, M	-68.5	-73.1	-52.0
PATH ANGLE, DEG.	-2.8	-3.7	-3.7
CLOSEST APPROACH, M	130.0	146.0	122.5
PATH SPEED, M/SEC	73.9	74.2	72.1
NORMALIZED THRUST, N	18405.8	22809.3	21506.1
SLANT RANGE, M	176.2	189.8	160.2
TEMPERATURE, DEG. CENT.	16.0	18.2	17.1
RELATIVE HUMIDITY, PERCENT	34.9	30.4	32.9
UNCORRECTED LEVELS			
DURATION FACTOR, PNDB	-4.3	-4.8	-5.0
TONE BAND, KHZ	0.0	2.5	4.0
TONE CORRECTION, PNDB	0.0	1.4	1.3
PNLTM, PNDB	107.9	108.2	109.3
EPNL, EPNDB	103.6	103.5	104.3
OASPL, DB	95.2	95.9	95.8
DBA, DB	93.5	92.8	93.4
CORRECTED LEVELS			
TONE BAND, KHZ	0.0	2.5	4.0
TONE CORRECTION, PNDB	0.0	1.4	1.3
WEATHER CORRECTION, EPNDB	2.9	2.5	2.9
PATH CORRECTION, EPNDB	1.7	3.1	1.0
SPEED CORRECTION, EPNDB	.0	.0	-.1
DURATION CORRECTION, EPNDB	-.6	-1.1	-.4
THRUST CORRECTION, EPNDB	0.0	.7	1.3
PNLTM, PNDB	112.5	113.8	113.2
EPNL, EPNDB	107.6	108.6	109.1
OASPL, DB	98.5	99.4	97.9
DBA, DB	97.8	97.5	96.5

Table 7b. - Summary of hardwall data analyses.

English System

	Takeoff correction					Cutback correction		
RUN NUMBER	37	38	43	45	47	39	40	41
OVERHEAD TIME	4:59:10.8	5:11:32.9	5:54:41.7	6:10:57.5	6:27:17.3	5:20: 2.7	5:28:24.2	5:36:57.2
TIME OF PNLTM	4:59:14.0	5:11:36.5	5:54:47.5	6:11: 1.5	6:27:21.0	5:20: 6.5	5:28:29.0	5:37: 2.0
REFERENCE CONDITIONS								
ALTITUDE, FT	2147.0	2147.0	2147.0	2147.0	2147.0	1959.0	1959.0	1959.0
LATERAL DISPLACEMENT, FT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	8.1	8.1	8.1	8.1	8.1	4.4	4.4	4.4
CLOSEST APPROACH, FT	2125.7	2125.7	2125.7	2125.7	2125.7	1953.3	1953.3	1953.3
PATH SPEED, FT/SEC	301.7	301.7	301.7	301.7	301.7	303.1	303.1	303.1
NORMALIZED THRUST, LBF	12892.0	12892.0	12892.0	12892.0	12892.0	9007.0	9007.0	9007.0
SLANT RANGE, FT	2411.6	2346.2	2627.6	2364.9	2298.5	2217.6	2315.3	2309.7
TEMPERATURE, DEG. FAHR.	77.0	77.0	77.0	77.0	77.0	77.0	77.0	77.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS								
ALTITUDE, FT	1356.5	1720.4	1598.2	1664.3	1710.5	1537.0	1694.0	1707.0
LATERAL DISPLACEMENT, FT	-295.9	-400.6	-164.0	-147.8	-244.3	-228.6	-100.8	-198.6
PATH ANGLE, DEG.	6.6	7.1	6.5	2.9	2.2	4.5	4.1	4.2
CLOSEST APPROACH, FT	1379.6	1753.6	1596.4	1666.7	1726.6	1549.2	1692.7	1714.0
PATH SPEED, FT/SEC	324.3	324.4	311.8	310.6	316.8	319.7	317.9	319.5
NORMALIZED THRUST, LBF	11117.0	12800.0	10672.0	8248.0	6974.0	9162.0	9215.0	9195.0
SLANT RANGE, FT	1565.2	1935.5	2123.5	1856.6	1867.0	1758.9	2006.4	2026.7
TEMPERATURE, DEG. FAHR.	58.3	59.7	65.0	65.2	62.0	60.0	61.0	62.9
RELATIVE HUMIDITY, PERCENT	26.0	28.7	15.8	12.8	16.6	21.6	19.3	17.4
UNCORRECTED LEVELS								
DURATION FACTOR, PNDB	-1.8	-.4	-.3	-1.4	-3.9	-1.7	-1.0	-1.5
TONE BAND, KHZ	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
TONE CORRECTION, PNDB	2.5	2.6	2.3	2.4	2.3	2.6	2.5	2.3
PNLTM, PNDB	105.0	104.6	101.1	95.6	92.5	99.2	97.7	97.7
EPNL, EPNDB	103.2	104.2	100.8	94.2	88.6	97.5	96.7	96.2
OASPL, DB	98.9	98.8	97.2	90.1	87.2	93.8	92.2	93.1
DBA, DB	93.0	92.6	88.0	83.8	81.1	86.5	84.9	84.9
CORRECTED LEVELS								
TONE BAND, KHZ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WEATHER CORRECTION, EPNDB	-.8	-.6	.0	1.7	1.0	-.5	-.0	.3
PATH CORRECTION, EPNDB	-4.8	-2.2	-3.1	-2.8	-2.4	-2.6	-1.6	-1.5
SPEED CORRECTION, EPNDB	.3	.3	.1	.1	.2	.2	.2	.2
DURATION CORRECTION, EPNDB	1.9	.8	1.2	1.1	.9	1.0	.6	.6
THRUST CORRECTION, EPNDB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PNLTM, PNDB	99.4	101.9	98.0	94.5	91.1	96.2	96.0	96.6
EPNL, EPNDB	99.8	102.6	99.0	94.3	88.3	95.8	95.9	95.8
OASPL, DB	94.6	96.7	94.6	88.4	85.5	91.6	90.9	92.0
DBA, DB	88.6	90.5	85.6	83.1	80.0	84.5	84.0	84.2

Table 7b. - Continued.

English System

		Takeoff with cutback			Landing Approach correction			
RUN NUMBER	42	29	31	36	3	4	11	12
OVERHEAD TIME	5:45:24.7	8: 9:41.6	8:30:12.0	9:19:11.9	10:11:43.9	10:20: 8.3	11:21:37.1	11:30:30.2
TIME OF PNLTM	5:45:29.0	8: 9:44.0	8:30:15.5	9:19:16.0	10:11:46.5	10:20:10.5	11:21:39.5	11:30:32.0
REFERENCE CONDITIONS								
ALTITUDE, FT	1959.0	1959.0	1959.0	1959.0	370.0	370.0	370.0	370.0
LATERAL DISPLACEMENT, FT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	4.4	4.4	4.4	4.4	-3.0	-3.0	-3.0	-3.0
CLOSEST APPROACH, FT	1953.3	1953.3	1953.3	1953.3	369.5	369.5	369.5	369.5
PATH SPEED, FT/SEC	303.1	303.1	303.1	303.1	240.7	240.7	240.7	240.7
NORMALIZED THRUST, LBF	9007.0	9007.0	9007.0	9007.0	5429.0	5429.0	5429.0	5429.0
SLANT RANGE, FT	2225.3	2059.2	2157.5	2196.9	570.5	504.1	526.2	448.4
TEMPERATURE, DEG. FAHR.	77.0	77.0	77.0	77.0	77.0	77.0	77.0	77.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS								
ALTITUDE, FT	1699.6	1315.8	1588.3	1750.4	371.5	401.4	387.6	388.7
LATERAL DISPLACEMENT, FT	130.7	-319.8	-25.4	-318.4	-227.4	-163.2	-165.4	-203.4
PATH ANGLE, DEG.	3.9	3.6	3.5	4.6	-3.3	-3.5	-3.8	-3.3
CLOSEST APPROACH, FT	1700.7	1351.6	1585.5	1773.6	435.0	432.6	420.6	438.1
PATH SPEED, FT/SEC	315.7	328.5	334.7	332.0	266.2	254.4	242.4	244.2
NORMALIZED THRUST, LBF	9150.0	9103.0	9268.0	9176.0	6079.0	5766.0	4808.0	4517.0
SLANT RANGE, FT	1937.5	1424.8	1751.3	1994.8	671.7	590.3	599.0	531.7
TEMPERATURE, DEG. FAHR.	63.7	56.0	58.5	66.0	66.0	65.0	61.5	61.1
RELATIVE HUMIDITY, PERCENT	16.9	36.1	31.1	28.3	28.5	30.1	35.5	36.0
UNCORRECTED LEVELS								
DURATION FACTOR, PNDB	-1.2	-1.7	-1.3	-1.0	-5.2	-4.8	-5.0	-4.4
TONE BAND, KHZ	4.0	10.0	4.0	4.0	2.5	2.5	4.0	4.0
TONE CORRECTION, PNDB	2.6	.7	1.9	2.5	1.2	1.0	1.3	1.1
PNLTM, PNDB	97.8	99.9	99.4	98.2	111.7	110.1	108.6	107.7
EPNL, EPNDB	96.5	98.2	98.1	97.2	106.5	105.2	103.6	103.3
OASPL, DB	92.5	94.1	93.0	92.2	99.8	97.6	95.7	94.2
DBA, DB	84.6	89.6	87.0	86.2	96.6	95.0	92.9	92.2
CORRECTED LEVELS								
TONE BAND, KHZ	0.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0
TONE CORRECTION, PNDB	0.0	0.0	0.0	0.0	1.4	1.1	1.4	1.2
WEATHER CORRECTION, EPNDB	.1	1.5	.2	-.1	3.5	3.2	3.1	2.8
PATH CORRECTION, EPNDB	-1.6	-4.5	-2.5	-1.1	2.0	1.9	1.6	2.0
SPEED CORRECTION, EPNDB	.2	.3	.4	.4	.4	.2	.0	.1
DURATION CORRECTION, EPNDB	.6	1.6	.9	.4	-.7	-.7	-.6	-.7
THRUST CORRECTION, EPNDB	0.0	-.2	-.6	-.4	0.0	0.0	0.0	0.0
PNLTM, PNDB	96.3	96.9	97.1	97.0	117.3	115.1	113.3	112.5
EPNL, EPNDB	95.9	97.0	96.5	96.4	111.8	109.8	107.7	107.4
OASPL, DB	91.3	90.4	90.9	91.2	102.6	100.4	98.1	97.2
DBA, DB	84.0	85.7	84.9	85.2	100.7	98.9	96.5	96.1

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Table 7b. - Concluded.

English System

		Landing Approach	
RUN NUMBER	13	5	10
OVERHEAD TIME	11:38:35.8	10:28:20.7	11:12:48.5
TIME OF PNLTM	11:38:38.0	10:28:23.0	11:12:50.5
REFERENCE CONDITIONS			
ALTITUDE, FT	370.0	370.0	370.0
LATERAL DISPLACEMENT, FT	0.0	0.0	0.0
PATH ANGLE, DEG.	-3.0	-3.0	-3.0
CLOSEST APPROACH, FT	369.5	369.5	369.5
PATH SPEED, FT/SEC	240.7	240.7	240.7
NORMALIZED THRUST, LBF	5429.0	5429.0	5429.0
SLANT RANGE, FT	501.0	480.5	463.3
TEMPERATURE, DEG. FAHR.	77.0	77.0	77.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0
ACTUAL CONDITIONS			
ALTITUDE, FT	362.7	415.5	364.5
LATERAL DISPLACEMENT, FT	-224.8	-239.8	-170.6
PATH ANGLE, DEG.	-2.8	-3.7	-3.7
CLOSEST APPROACH, FT	426.3	479.0	401.8
PATH SPEED, FT/SEC	242.4	243.4	236.5
NORMALIZED THRUST, LBF	4138.0	5128.0	4835.0
SLANT RANGE, FT	578.1	622.8	525.5
TEMPERATURE, DEG. FAHR.	60.8	64.8	62.8
RELATIVE HUMIDITY, PERCENT	34.9	30.4	32.9
UNCORRECTED LEVELS			
DURATION FACTOR, PNDB	-4.3	-4.8	-5.0
TONE BAND, KHZ	0.0	2.5	4.0
TONE CORRECTION, PNDB	0.0	1.4	1.3
PNLTM, PNDB	107.9	108.2	109.3
EPNL, EPNDB	103.6	103.5	104.3
OASPL, DB	95.2	95.9	95.8
DBA, DB	93.5	92.8	93.4
CORRECTED LEVELS			
TONE BAND, KHZ	0.0	2.5	4.0
TONE CORRECTION, PNDB	0.0	1.4	1.3
WEATHER CORRECTION, EPNDB	2.9	2.5	2.9
PATH CORRECTION, EPNDB	1.7	3.1	1.0
SPEED CORRECTION, EPNDB	.0	.0	-.1
DURATION CORRECTION, EPNDB	-.6	-1.1	-.4
THRUST CORRECTION, EPNDB	0.0	.7	1.3
PNLTM, PNDB	112.5	113.8	113.2
EPNL, EPNDB	107.6	108.6	109.1
OASPL, DB	98.5	99.4	97.9
DBA, DB	97.8	97.5	96.5

Table 8a. - Summary of Refan II data analyses.

Metric System

	Takeoff with cutback			Landing Approach	
RUN NUMBER	17R	18R	22R	1R	6R
OVERHEAD TIME	8:33:50.5	8:45:56.5	9:23:46.7	10:32:49.3	11:17:57.8
TIME OF PNLTM	8:33:54.0	8:45:59.0	9:23:50.5	10:32:51.5	11:18: .5
REFERENCE CONDITIONS					
ALTITUDE, M	706.5	706.5	706.5	112.8	112.8
LATERAL DISPLACEMENT, M	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	4.7	4.7	4.7	-3.0	-3.0
CLOSEST APPROACH, M	704.1	704.1	704.1	112.6	112.6
PATH SPEED, M/SEC	92.7	92.7	92.7	72.8	72.8
NORMALIZED THRUST, N	42131.5	42131.5	42131.5	23823.5	23823.5
SLANT RANGE, M	755.6	721.4	747.0	148.6	165.0
TEMPERATURE, DEG. CENT.	25.0	25.0	25.0	25.0	25.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS					
ALTITUDE, M	558.6	567.4	658.1	122.0	120.5
LATERAL DISPLACEMENT, M	1.8	-4.7	-12.3	-69.3	-72.9
PATH ANGLE, DEG.	4.4	4.5	4.8	-2.6	-3.2
CLOSEST APPROACH, M	557.0	565.7	655.9	140.2	140.7
PATH SPEED, M/SEC	99.8	102.0	99.9	76.1	75.1
NORMALIZED THRUST, N	40298.9	40734.8	39573.9	24072.6	21737.4
SLANT RANGE, M	597.7	579.6	695.8	185.1	206.1
TEMPERATURE, DEG. CENT.	14.6	15.3	19.3	17.9	16.1
RELATIVE HUMIDITY, PERCENT	33.2	32.1	27.8	31.6	36.9
UNCORRECTED LEVELS					
DURATION FACTOR, PNDB	-4.7	-4.4	-6.4	-4.9	-5.4
TONE BAND, KHZ	4.0	4.0	4.0	0.0	6.3
TONE CORRECTION, PNDB	1.8	1.5	2.4	0.0	.5
PNLTM, PNDB	92.7	91.8	90.5	100.6	100.8
EPNL, EPNDB	88.0	87.4	82.1	95.6	95.4
OASPL, DB	87.0	86.4	84.8	92.9	92.9
DBA, DB	79.7	80.1	77.8	88.7	88.3
CORRECTED LEVELS					
TONE BAND, KHZ	0.0	0.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	0.0	0.0	0.0	0.0	0.0
WEATHER CORRECTION, EPNDB	-.2	.3	-.4	1.8	1.1
PATH CORRECTION, EPNDB	-2.9	-2.7	-.9	2.4	2.5
SPEED CORRECTION, EPNDB	.3	.4	.3	.2	.1
DURATION CORRECTION, EPNDB	1.0	1.0	.3	-1.0	-1.0
THRUST CORRECTION, EPNDB	1.2	.9	1.7	-.1	.9
PNLTM, PNDB	89.6	89.5	89.2	104.7	104.3
EPNL, EPNDB	87.4	87.4	83.1	99.0	99.0
OASPL, DB	84.6	84.2	84.0	95.1	95.1
DBA, DB	77.1	77.7	76.9	91.4	91.0

Table 8b. - Summary of Refan II data analyses.

English System

	Takeoff with cutback			Landing Approach	
RUN NUMBER	17R	18R	22R	1R	6R
OVERHEAD TIME	8:33:50.5	8:45:56.5	9:23:46.7	10:32:49.3	11:17:57.8
TIME OF PNLTM	8:33:54.0	8:45:59.0	9:23:50.5	10:32:51.5	11:18: .5
REFERENCE CONDITIONS					
ALTITUDE, FT	2318.0	2318.0	2318.0	370.0	370.0
LATERAL DISPLACEMENT, FT	0.0	0.0	0.0	0.0	0.0
PATH ANGLE, DEG.	4.7	4.7	4.7	-3.0	-3.0
CLOSEST APPROACH, FT	2310.1	2310.1	2310.1	369.5	369.5
PATH SPEED, FT/SEC	304.0	304.0	304.0	238.7	238.7
NORMALIZED THRUST, LBF	9472.0	9472.0	9472.0	5356.0	5356.0
SLANT RANGE, FT	2479.1	2366.8	2450.7	487.6	541.3
TEMPERATURE, DEG. FAHR.	77.0	77.0	77.0	77.0	77.0
RELATIVE HUMIDITY, PERCENT	70.0	70.0	70.0	70.0	70.0
ACTUAL CONDITIONS					
ALTITUDE, FT	1832.8	1861.7	2159.0	400.4	395.4
LATERAL DISPLACEMENT, FT	6.0	-15.4	-40.3	-227.4	-239.1
PATH ANGLE, DEG.	4.4	4.5	4.8	-2.6	-3.2
CLOSEST APPROACH, FT	1827.4	1856.0	2151.8	460.1	461.5
PATH SPEED, FT/SEC	327.3	334.7	327.8	249.7	246.3
NORMALIZED THRUST, LBF	9060.0	9158.0	8897.0	5412.0	4887.0
SLANT RANGE, FT	1961.0	1901.6	2287.7	607.2	676.2
TEMPERATURE, DEG. FAHR.	58.3	59.5	66.8	64.2	61.0
RELATIVE HUMIDITY, PERCENT	33.2	32.1	27.8	31.6	36.9
UNCORRECTED LEVELS					
DURATION FACTOR, PNDB	-4.7	-4.4	-8.4	-4.9	-5.4
TONE BAND, KHZ	4.0	4.0	4.0	0.0	6.3
TONE CORRECTION, PNDB	1.8	1.5	2.4	0.0	.5
PNLTM, PNDB	92.7	91.8	90.5	100.6	100.8
EPNL, EPNDB	88.0	87.4	82.1	95.6	95.4
OASPL, DB	87.0	86.4	84.8	92.9	92.9
DBA, DB	79.7	80.1	77.8	88.7	88.3
CORRECTED LEVELS					
TONE BAND, KHZ	0.0	0.0	0.0	0.0	0.0
TONE CORRECTION, PNDB	0.0	0.0	0.0	0.0	0.0
WEATHER CORRECTION, EPNDB	-.2	.3	-.4	1.8	1.1
PATH CORRECTION, EPNDB	-2.9	-2.7	-.9	2.4	2.5
SPEED CORRECTION, EPNDB	.3	.4	.3	.2	.1
DURATION CORRECTION, EPNDB	1.0	1.0	.3	-1.0	-1.0
THRUST CORRECTION, EPNDB	1.2	.9	1.7	-.1	.9
PNLTM, PNDB	89.6	89.5	89.2	104.7	104.3
EPNL, EPNDB	87.4	87.4	83.1	99.0	99.0
OASPL, DB	84.6	84.2	84.0	95.1	95.1
DBA, DB	77.1	77.7	76.9	91.4	91.0

TABLE 9

COMPARISON OF REFAN I, HARDWALL, AND REFAN II CENTERLINE

TAKEOFF WITH CUTBACK AND LANDING APPROACH EPNL's

AIRCRAFT	AVERAGE NOISE LEVELS, EPNdB					
	TAKEOFF WITH CUTBACK			50° FLAP LANDING APPROACH		
Hardwall	96.6	96.6	96.6	108.9	108.9	108.9
Refan I	89.8	--	--	98.9	--	--
Refan II	--	86.0	--	--	99.0	--
Refan I + Refan II	--	--	87.5	--	--	98.9
Noise Reduction	6.7	10.6	9.1	10.0	9.9	10.0

Figure 1. - McDonnell Douglas DC-9 test aircraft equipped with refanned JT8D-109 engines.

Figure 2. - USAF C-9A test aircraft equipped with hardwall JT8D-9 engines.

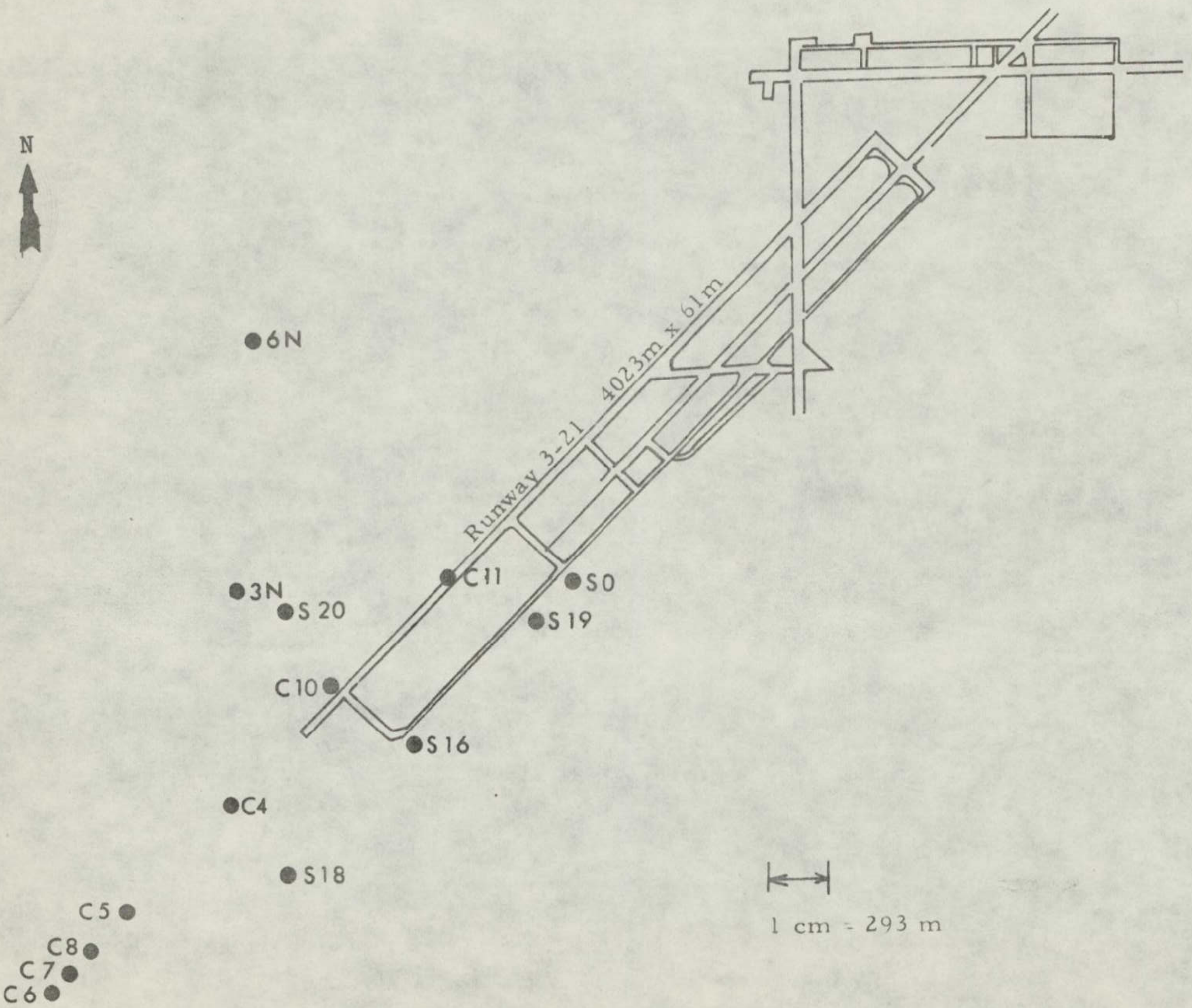

Figure 3. - Microphone locations at the DACO Yuma test site for DC-9 flyover noise measurements.

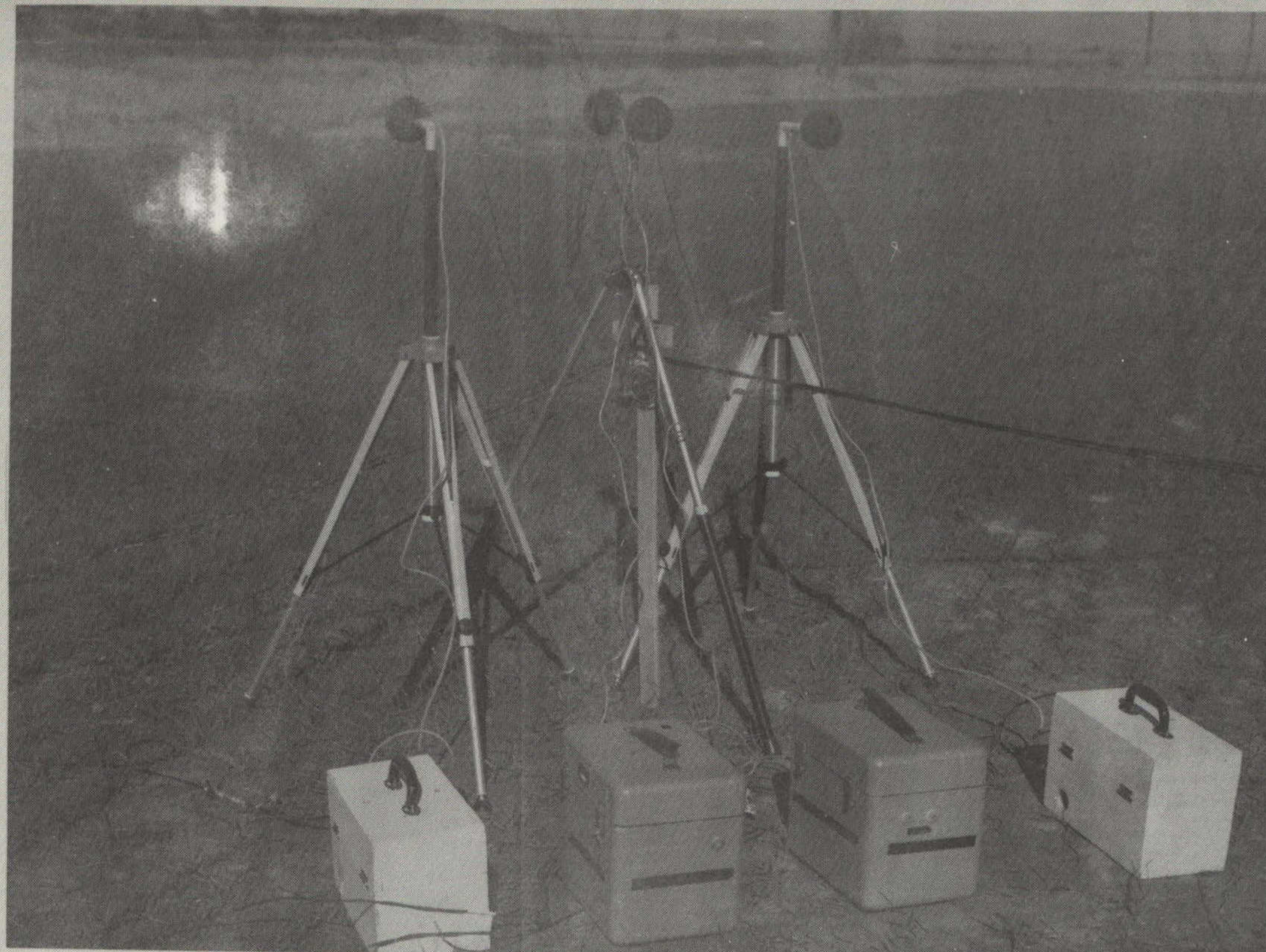

Figure 4. - Typical microphone array used for parallel flyover noise measurements. NASA microphones are 45.7 cm either side of the DACO microphones at 1.2 m height and oriented for grazing incidence.

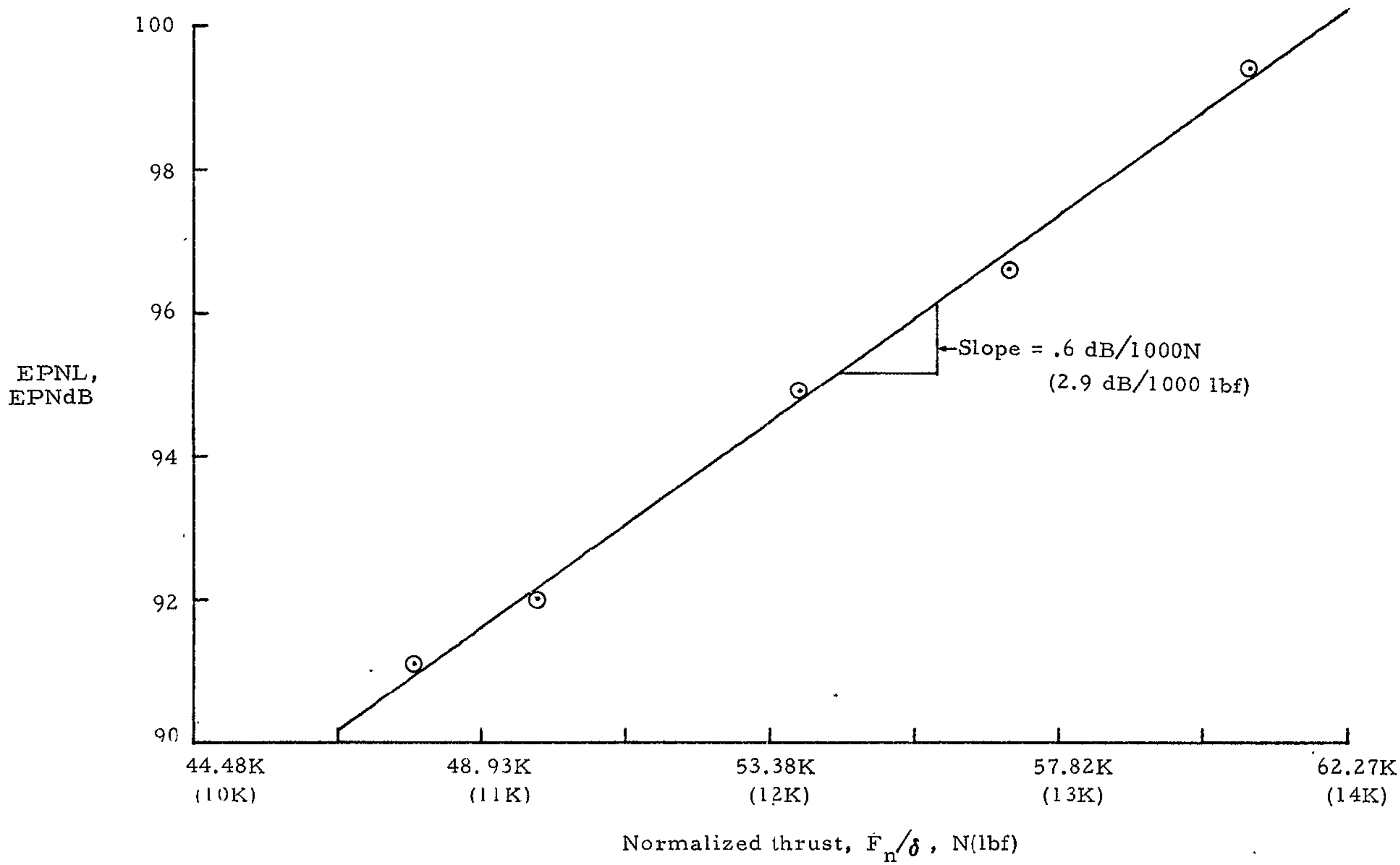

Figure 5. - Refan takeoff correction curve. Reference thrust for takeoff with cutback is 42131 N(9472lbf).

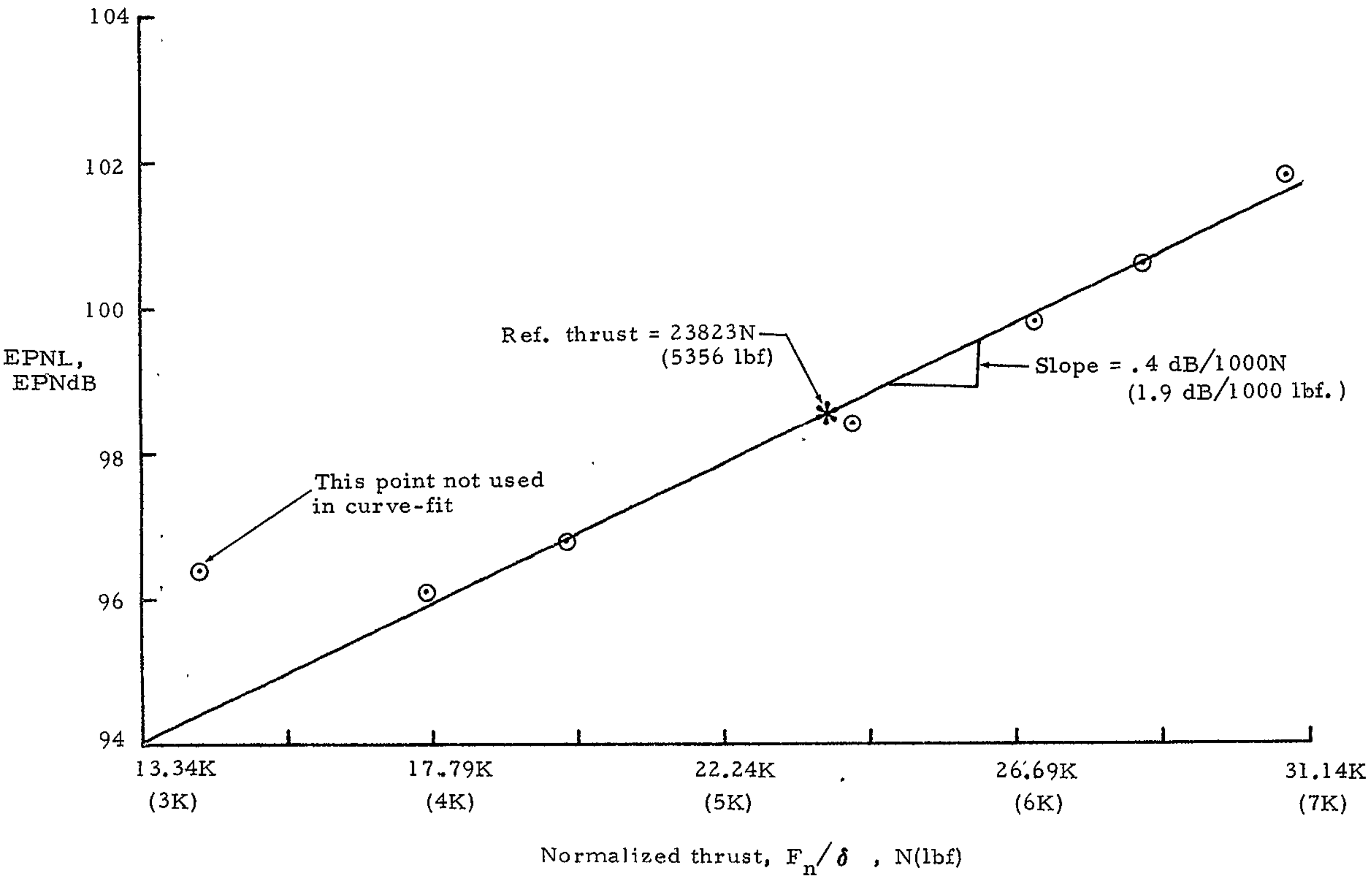

Figure 6 - Refan landing approach correction curve.

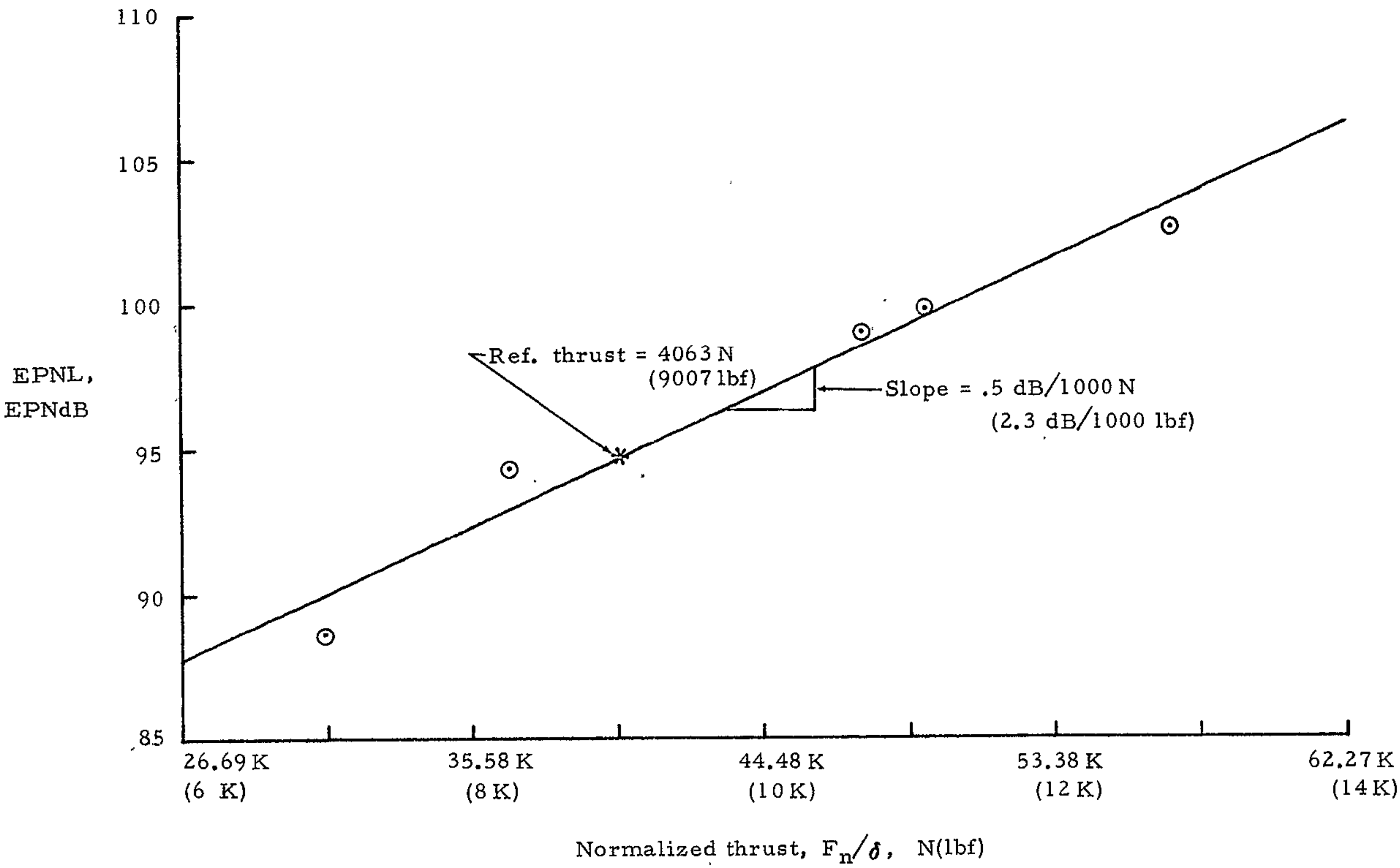

Figure 7 - Hardwall takeoff correction curve.

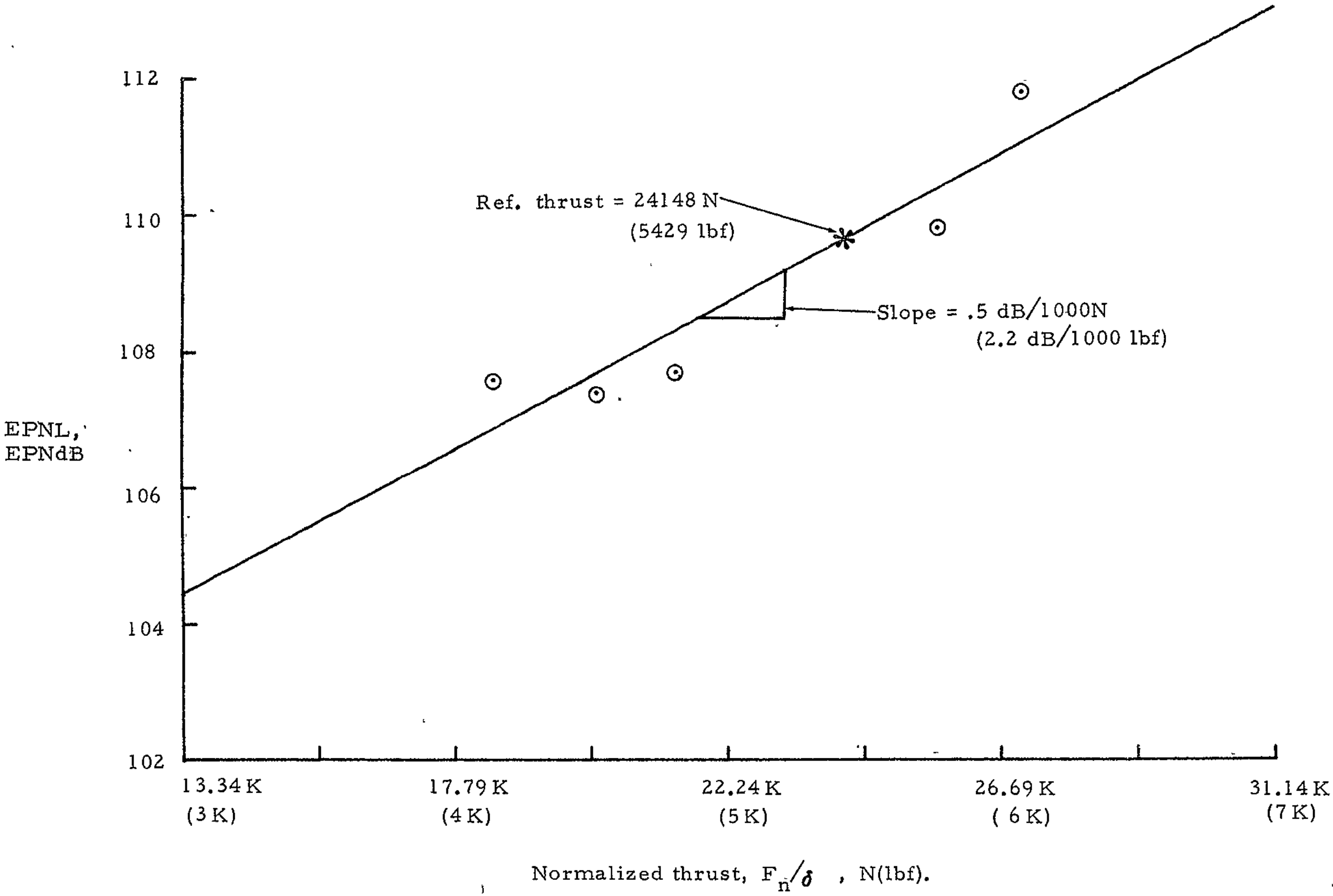

Figure 8.- Hardwall landing approach correction curve.

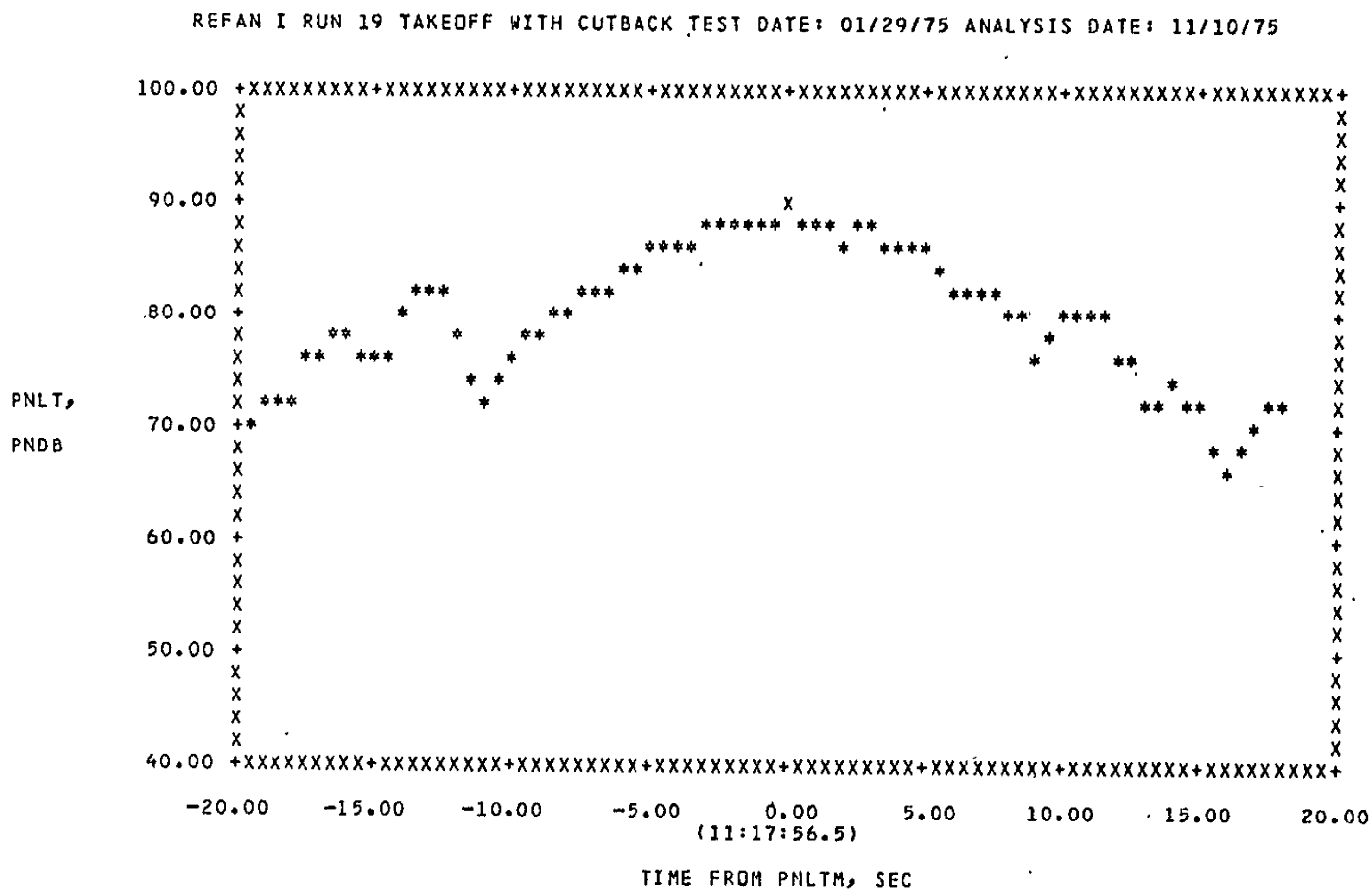

Figure 4. - Refan I PNLT time history.

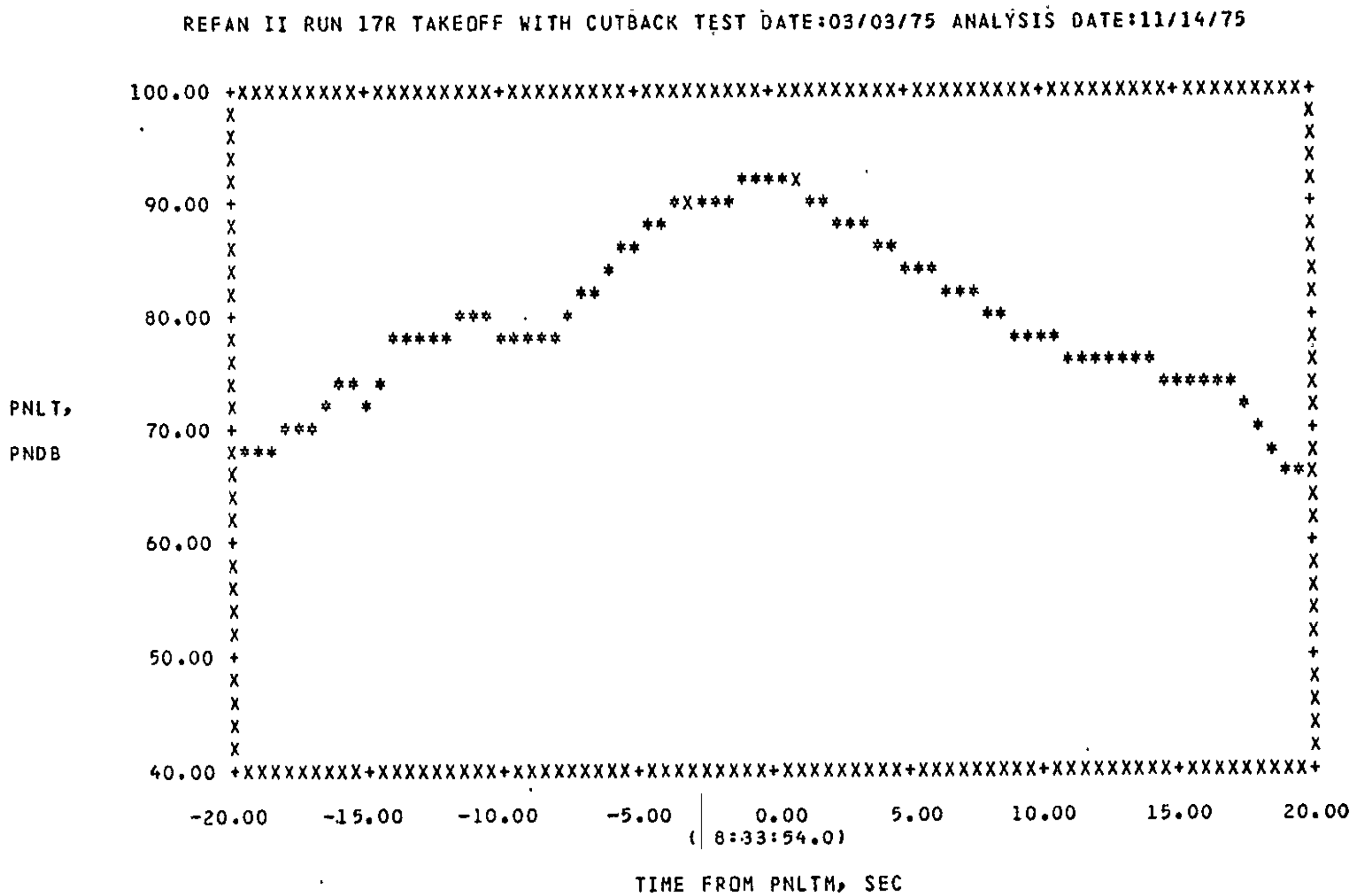

Figure 10. - Refan II PNLT time history.

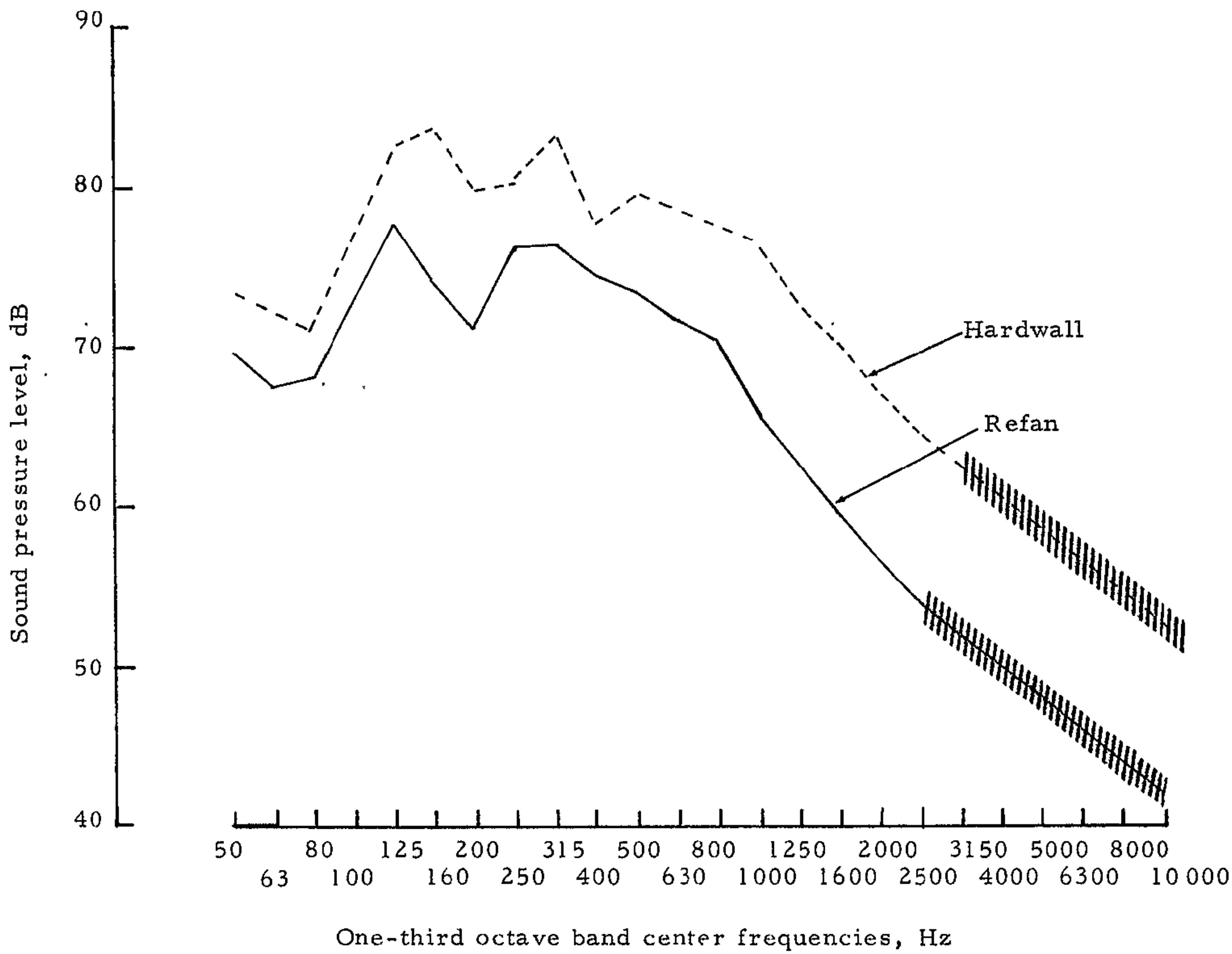

Figure 11. - Comparison of hardwall and refan PNLTM weather and path corrected one-third octave band spectra for takeoff with cutback.

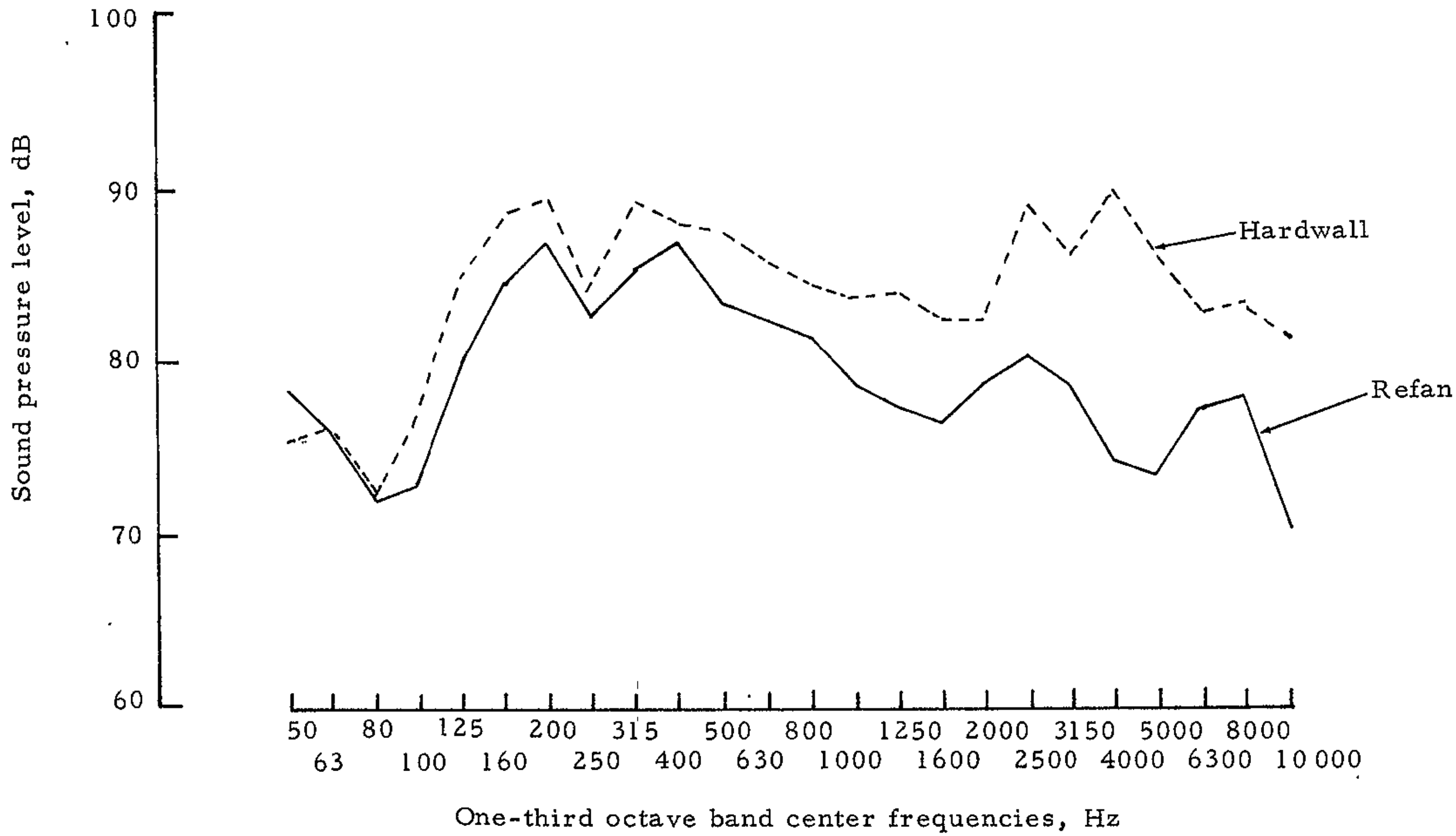

Figure 12. - Comparison of hardwall and refan PNLTM weather and path corrected one-third octave band spectra for 50° flap landing approach.